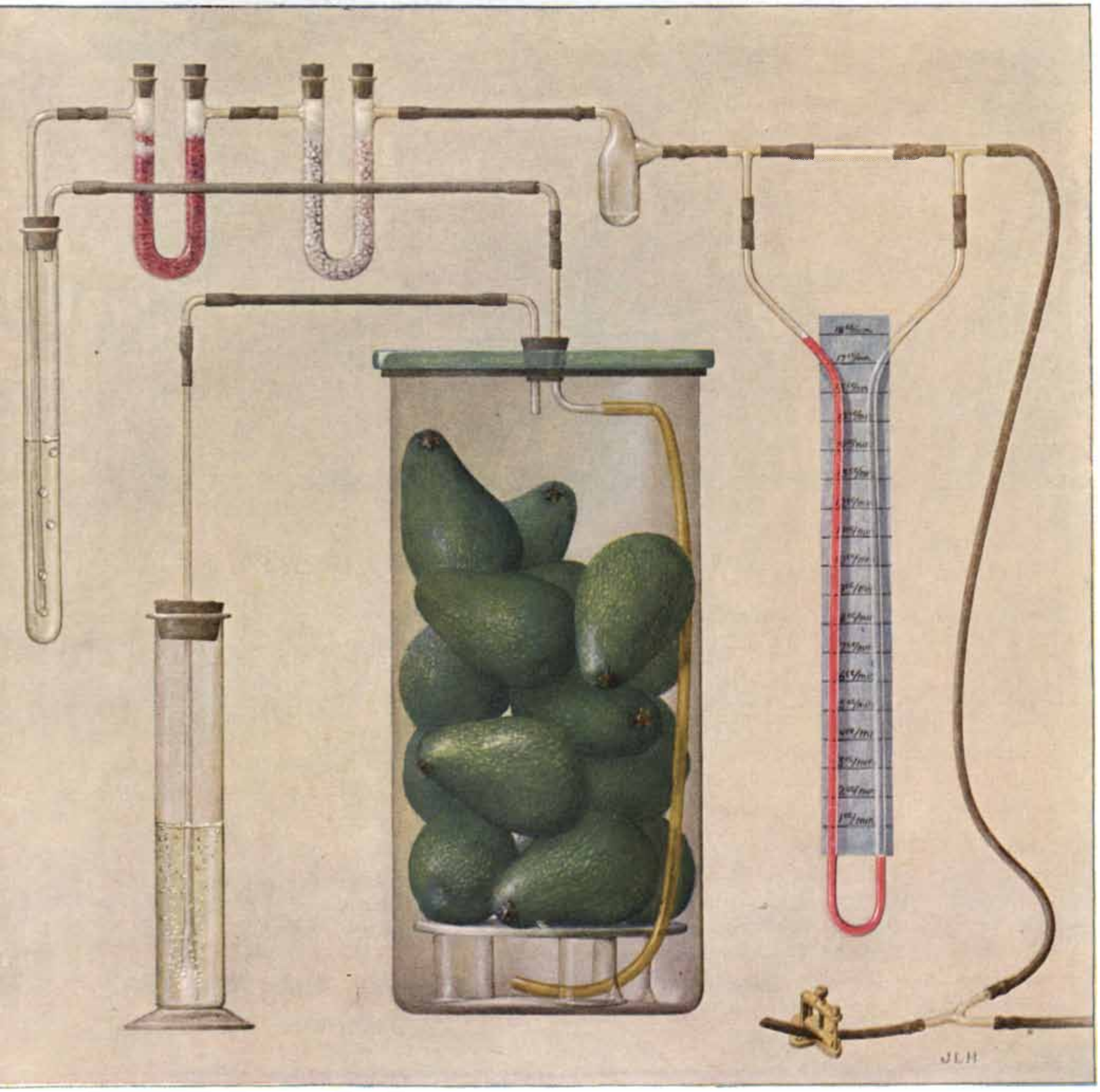
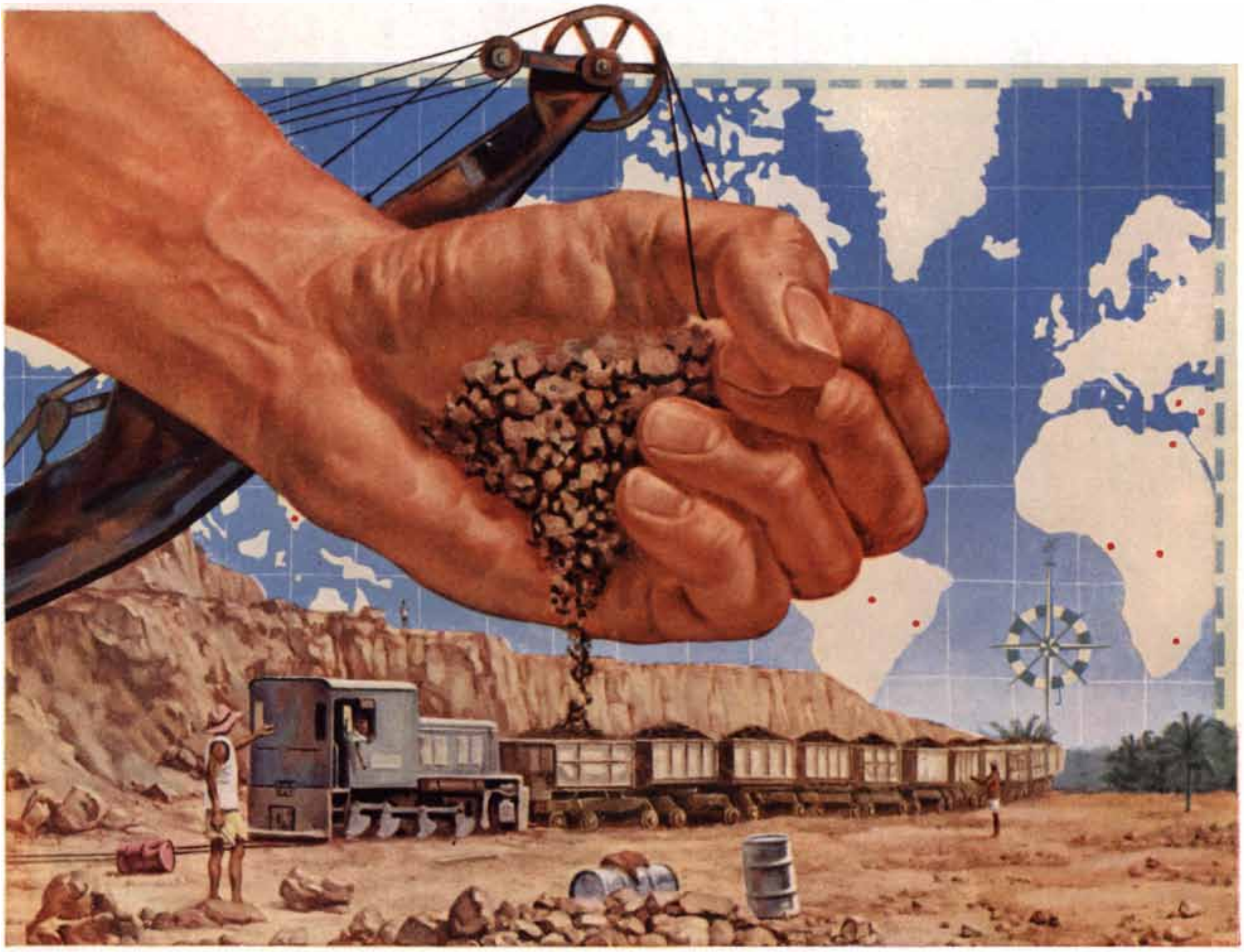
SCIENTIFIC AMERICAN



AVOCADOS IN THE LABORATORY

FIFTY CENTS

May 1954



The metal that thrives on punishment

Steel serves you better when manganese is added
—because the harder it works, the tougher it gets

EVER WATCH a power shovel bite into earth and rock? And wonder how the teeth of the steel bucket can endure such punishment? The amazing answer is that the teeth not only endure such treatment—they actually get harder because of it!

MANGANESE HOLDS THE SECRET—The story behind this remarkable steel is the unusual metal called *manganese.* The hundreds of thousands of tons of manganese required each year by steel and other metal-making industries are obtained by refining huge quantities of ore that come from mines in widely scattered points across the face of the globe.

ADDED TO STEEL—All steel contains manganese. A small amount "cleanses" molten steel and removes impurities. A larger amount of manganese makes the steel tougher and stronger.

FROM ORE TO ALLOY—Transforming raw ores into a variety of manganese alloys for the metal-producing industries is one of the many important jobs of the people of Union Carbide.

FREE: *Learn how ALLOYS, CARBONS, GASES, CHEMICALS, and PLASTICS improve many things that you use. Ask for the 1954 edition of "Products and Processes" booklet C.*

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LINDE Oxygen

Photographed through courtesy of Macy's New York

CAUGHT!—by Silent Sounds

Suddenly, the lights snap on. Someone yells—

"Don't move or we shoot!"

How had the burglar been detected? No one saw him enter. There was no watchman. And no sign of an alarm system.

No obvious sign, that is. But there *was* a system — the Alertronic Burglar Alarm.

This unusual protective device operates by sending out 19,200 cycle-a-second sound waves, too high for human ears to hear. The slightest movement of an intruder disturbs these waves of silent sound and activates the alarm. It's so sensitive that even the motion of heated air rising from a fire sets it off.

What produces the vibrations? Two slender nickel rods—and a principle of physics called *magnetostriction* (the peculiar way they change size in a changing magnetic field).

Putting magnetostriction to work in this ultrasonic burglar alarm — the first ever to be approved by The Underwriters' Laboratories—wasn't an overnight job. It was twelve years ago that the inventor made his first experiments.

The search for a material with necessary magnetostrictive properties ended when he came to Inco — for nickel proved to be the material he was seeking.

And, as it turned out, he got more than a metal from Inco ...

In the years that have passed, he has found Inco always ready to help in supplying information on the physical and mechanical properties of Inco Nickel Alloys and other metals . . . on the technical aspects of magnetostriction ... and on questions involving metal fabrication.

This same type of friendly cooperation, of course, is available to you for the asking. Let's get together on *your* problem.

The International Nickel Company, Inc.
67 Wall Street New York 5, N. Y.

Inco Nickel Alloys

MONEL® • "R"® MONEL • "K"® MONEL "KR"® MONEL • "S"® MONEL • INCONEL® INCONEL "X"® • INCONEL "W"® INCOLOY® • NIMONIC® ALLOYS • NICKEL LOW CARBON NICKEL • DURANICKEL®

LETTERS

Sirs:

We were pleased with Lawrence P. Lessing's article on the National Science Foundation [Scientific American, March], which caught the enthusiasm as well as the growing pains of this young agency devoted to the cause of basic research in the U. S.

Among several minor errors of fact in the article there are two to which I direct your attention. It is stated that "the NSF has been able to support only about half of the worthy projects proposed to it." Actually during its first two years, a total of 805 proposals for $15.9 million were evaluated. Of these 269 (33 per cent) for $2.77 million (17 per cent) were approved. Currently three out of four proposals received are considered worthy of support by the reviewing panels. About one out of four is supported.

After listing special NSF studies in the fields of physiology, psychology and applied mathematics, the writer states that NSF plans to go through all the neglected sciences in the same way. This is correct except for the descriptive "neglected." These particular fields were selected for special study for exactly the opposite reason—because they are among the most active, fast-growing areas in present-day science. On the other hand, the Foundation has tried through its research support program to encourage

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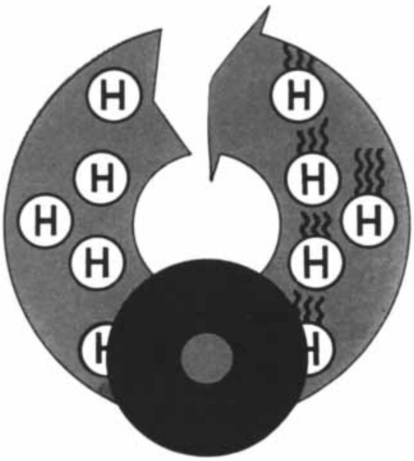
BUSINESS IN MOTION

To our Colleagues in American Business . . .

For many years the electrical industry has been asking for larger and larger generators, in order to meet the tremendous growth in demand. However, two limitations have been imposed upon generator output. One is physical size, which is limited by the dimensions of railroad tunnels and bridges. The other is the problem of heat dissipation. Temperatures within the generator must be held down to avoid damage to insulation. Cooling the stator is not too great a problem, but removing heat from the spinning rotor is not easy. In the conventional design, heat flows from the copper rotor coils through the insulation to the steel rotor body, from which it is removed by a blast of air or hydrogen.



Since the insulation is a formidable barrier to heat as well as to electricity, it became evident long ago that some way should be found to cool the rotor coils directly instead of indirectly. Various methods were tried, with varying success. New and successful designs make use of extruded copper shapes. The shapes fit together in such a manner as to form hollow copper conductors for the rotor coils.

The idea was fundamentally simple, but as is so often the case, reducing it to practicality was not easy. Some said the shapes could not be extruded. Revere, however, tackled the problem, and collaborated closely with the generator designers over a period of months. Finally all requirements were adjusted, and production began. Specifications for the shapes are tight. They are extruded, drawn, and straightened. Tolerances are close. Finish is important, since irregularities would damage the insulation. Special techniques were found to make 90-degree bends in the shapes, to complete the coils. Today generators embodying these designs are in successful operation. This is another marked advance by the electrical industry, which has consistently achieved greater efficiency, lower costs, and cheaper power.

One of the important things to remember about this development is that ways were found to overcome all handicaps. Close collaboration among many men on both sides did the trick.

If you have an idea for product improvement, or a new product, let us suggest that you search among your suppliers for advice. If one says it can't be done, perhaps another may say it can, given mutual adjustments. Just realize that the difficult is not necessarily the impossible; it may just take a little longer.

REVERE COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

***Executive Offices:* 230 Park Avenue, New York 17, N. Y.**

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certain relatively neglected fields, notably systematic biology.

ROBERT TUMBLESON

Head
Office of Scientific Information
National Science Foundation
Washington, D. C.

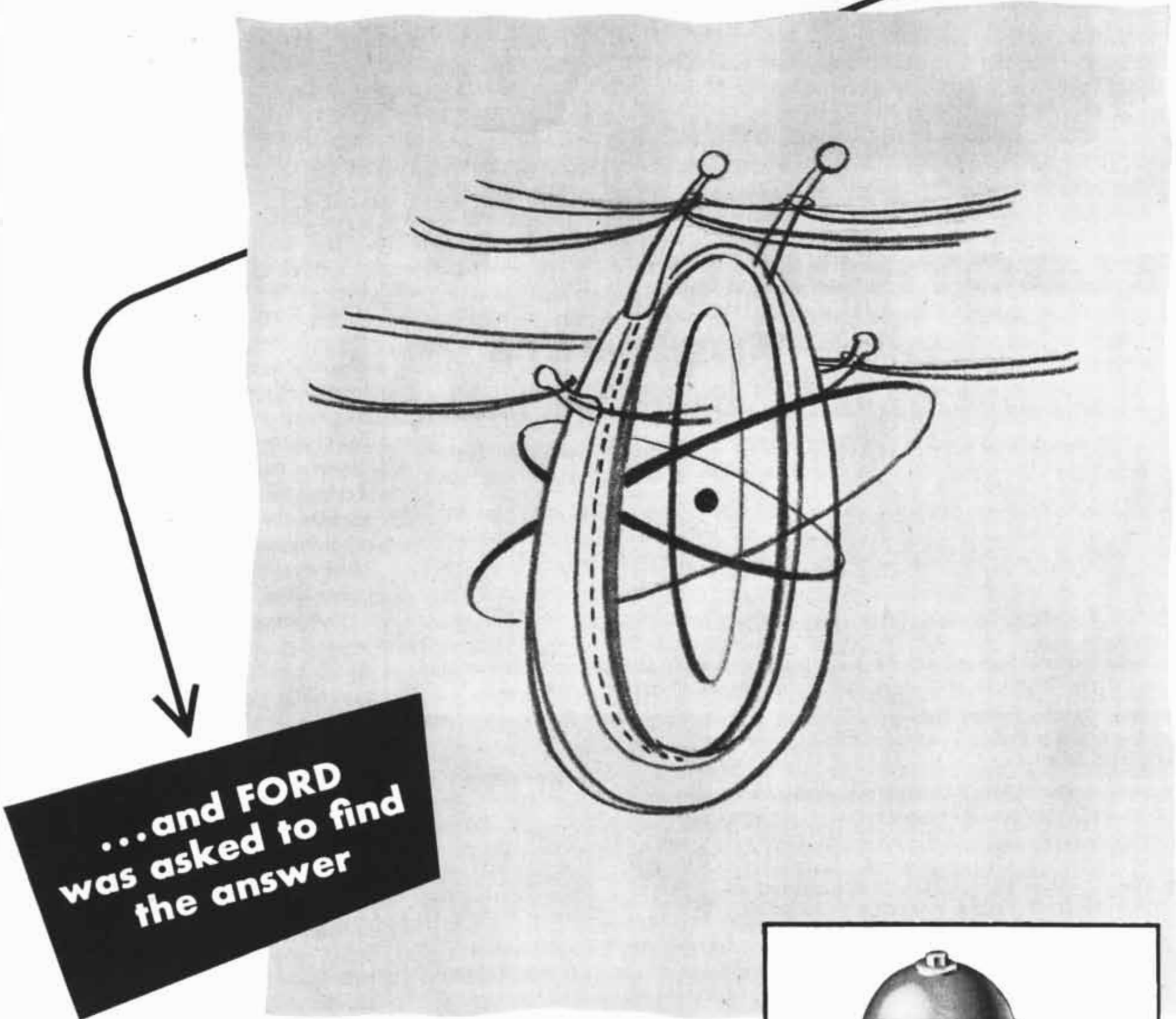
Sirs:

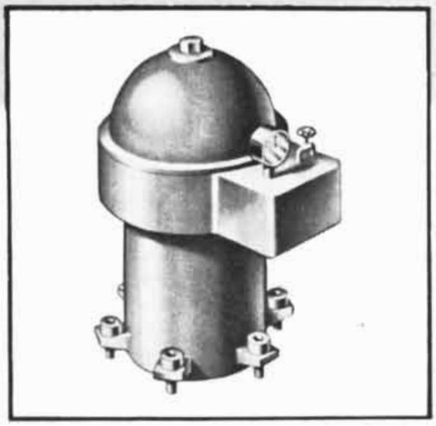
Please allow me a few comments on the recent article "The End of the Moas" by Edward S. Deevey, Jr. [SCIENTIFIC AMERICAN, February]. First I would like to question the distinction he makes between the Maoris of New Zealand and the people whom he refers to as "a pre-Maori people who hunted moas." The human bones which have been found in the moa hunters' camps definitely establish that these people were Polynesians indistinguishable from the Maoris, and not related to those early New Zealanders of mysterious origin, the Morioris, the last survivor of whom died in the Chatham Islands in the early 1930s. The moa hunters undoubtedly came from the same places as the later Maoris of the Great Fleet Migration of about A. D. 1350, so it would be more proper to speak of them as pre-Fleet Maoris.

There is strong evidence that one small species of moa, the *Megalapteryx*, survived until white traders came to New Zealand in the early 1800s. In a wild valley of the lake region of Otago there were found in 1949 several bones of this species in a Maori hunting-party camp. These bones were so cleanly cut that it is extremely likely that they were cut with a metal knife. Since the Maoris knew nothing of metal-working, any knives they possessed must have been obtained from the sealers at Foveaux Strait. Roger Duff, Director of the Canterbury Museum at Christchurch, New Zealand, concludes that we must seriously consider the possibility that some Megalapteryx may survive today. That is not nearly as unlikely as it may sound, in view of the number of unexplored valleys in southern New Zealand, and in view of the 1948 discovery in one of those valleys of the *Notornis*, which had been thought to be extinct.

While I was in New Zealand in 1952, several newspapers published a feature story concerning an old lady who, when she was a young girl in the 1870s in southern New Zealand, came running in to her parents one day with a story of having seen a funny animal. The description she gave was remarkably like that of a large Megalapteryx or a small *Euryap-*

HOW TO MAKE A HARNESS
for an Atom





Taming the monster power of a nuclear reactor requires precision control of all the elements. Ford Instrument is designing controls that seek and hold the optimum power level of the pile . . . and keep the rods so exactly set that the reactor's energy is harnessed . . . safely, securely.

This is typical of the problems that Ford has been given by the Armed Forces since 1915. For from the vast engineering and production facilities of the Ford Instrument Company, come the mechanical, hydraulic, electric, magnetic and electronic instruments that bring us our "tomorrows" today. Control problems of both Industry and the Military are Ford specialties.

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teryx. Of course some strange things happen in Otago. If you will recall, that is where a lady hit about seven or eight verified holes-in-one within a couple of months last year. Where that can happen, anything can happen.

J. EDGAR WILLIAMS

Department of Political Science
University of North Carolina
Chapel Hill, N. C.

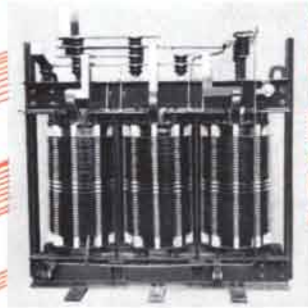
Sirs:

I am grateful for Mr. Williams' footnotes, since they touch on matters for which I had no space. I did not discuss the exceedingly interesting case of *Megalapteryx*, since this moa was not found in Pyramid Valley. Probably it was too much a forest-dweller to live there. *Notornis* was found there, but this bird is not a moa, and I reluctantly deleted a reference to its discovery from an early version of my article. Of course almost anything can happen in New Zealand, but I doubt that *Dinornis* remains to be found alive.

Not being an anthropologist I should probably not engage in debate with a social scientist, for the distinction between the Maori and the moa hunters is not mine but Duff's. However, Williams' point seems to be based on a misconception. Maori refers to a culture, not a race, whatever a race may be. Duff's book, to which I referred (but which I cannot readily consult in Denmark), gave evidence, which I thought convincing, that moa-hunter culture differed from Maori in several respects, apart from the hunting of moas. Archaeological taxonomists can debate whether an ancestral culture should be called an aspect or a stage, and whether the name of the historic Maori should be given to all aspects or stages of the Maori culture-type; they may even wish to decide whether the Maoris became Maoris (a) before they left Tahiti, (b) the moment they left the beach or (c) the moment they landed in New Zealand. But "the human bones which have been found in the moa hunters' camps" cannot "definitely establish" anything about culture, even if (as I very much doubt) they can tell us anything about the biological affinities of the Moriori.

EDWARD S. DEEVEY, JR.

Geologisk Rigsinstitut
Danmarks Geologiske Undersogelse
Charlottenlund, Denmark



MOLONEY CLASS-H SEALED DRY TYPE TRANSFORMER
uses Formica glass silicone barrier sheets and molded spacer bars. Design (at left) allows free circulation of nitrogen, provides maximum insulation at high temperatures. Three coils (center) form the heart of the transformer (right).

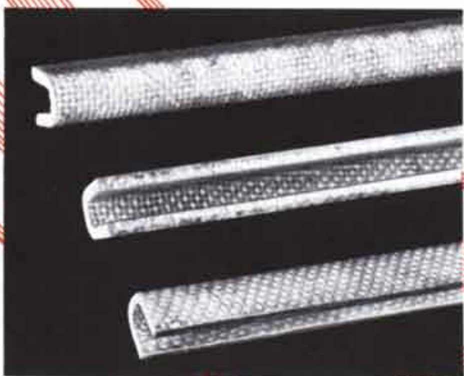
new Formica GLASS SILICONES

improve performance of sealed dry type transformers

Two new Formica glass silicone grades contribute materially to more efficient distribution of power. This miracle material not only provides dependable electrical insulation at temperatures up to 482° F., but is engineered to help keep transformer operating temperatures to a 'cool' 248° F!

With this 'assist' from Formica, transformer manufacturers like Moloney Electric Co., St. Louis, now build safer, smaller, lighter weight transformers . . . thus opening the door to new possibilities in power distribution *indoors*.

Formica's engineers have brought Formica's versatile properties into play in many other difficult electrical as well as chemical and mechanical applications. Our staff is ready to apply this same skill to help solve your laminated plastics problem. Simply write or wire us your requirements today. The Formica Co., 4593 Spring Grove Ave., Cincinnati 32, Ohio.



G-68 SPACER BARS *are molded, delivered ready to install, eliminate waste. U-shape allows free circulation of nitrogen, prevents 'hot-spots' from building up inside transformer.*

G-54 BARRIER SHEETS *retain 500 vpm dielectric strength at 482° F., have 2" bending radius in .025" thickness, come in sheet sizes up to 36" x 72". Thicknesses from .020" to .045".*

A TECHNICAL REPORT from Du Pont

Valve packings of "Teflon" withstand extremes of temperature and are not attacked by any chemicals normally encountered in industry.

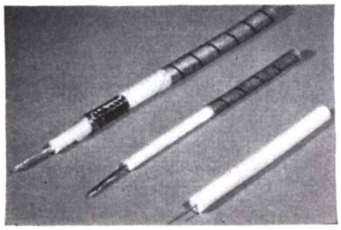
● *Properties and uses of Du Pont "Teflon" tetrafluoroethylene resin*

This plastic engineering material is remarkable for its chemical inertness, excellent dielectric properties, and the wide temperature range over which the properties of "Teflon" are unaffected.

"Teflon" absorbs no water as determined by A.S.T.M. test D570-42 and is self-lubricating. Du Pont "Teflon" has been widely used for chemical and electrical applications where service conditions are too severe for any other engineering material.

Listed on the opposite page are the properties of Du Pont "Teflon." By evaluating and using these properties, engineers and designers have developed many design and product improvements. Some of these applications are shown here.

Be sure to evaluate Du Pont "Teflon" in terms of your own product-design problems. Mail the coupon on the opposite page for additional information on the properties, applications and processing of this unique plastic engineering material, "Teflon."



Wires and cables with an insulation of "Teflon" are tough and flexible.

Coaxial connectors with inserts of "Teflon" have excellent electrical properties at high frequencies and temperatures.

Gaskets of "Teflon" are capable of continuous service at 500°F., have zero water absorption by A.S.T.M. test D570-42.

Spacers of "Teflon" for coaxial cables have low dielectric constant (2.0). Power factor is less than 0.0005 at high frequencies.

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Tough
Abrasion-Resistant
Strong in Thin Sections
Form Stability

ALATHON*
Polyethylene Resin
Excellent Dielectric Properties
Tough and Flexible Over a Wide Temperature Range
Tasteless, Odorless, Non-Toxic
Excellent Water Resistance

LUCITE*
Acrylic Resin
Clear, Transparent
Outdoor Durability
Excellent Range of Colors
Ability to Pipe Light

TEFLON*
Tetrafluoroethylene Resin
Heat Resistance
Chemical Inertness
Dielectric Properties
Non-Sticky Characteristics

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BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

TYPICAL PROPERTIES OF DU PONT "TEFLON"

CHEMICAL:

	METHOD
Resistant to: All chemicals except molten alkali metals and fluorine at elevated temperatures and pressures.	

MECHANICAL:

			METHOD
Tensile strength, 73°F.	1,800	LB./SQ. IN.	D638-49T
170°F.	1,100	LB./SQ. IN.	D638-49T
Elongation, 73°F.	110	%	D638-49T
170°F.	600	%	D638-49T
Modulus of elasticity, 77°F.	58,000	LB./SQ. IN.	D638-49T
Shear strength	3,800	LB./SQ. IN.	D732-46
Impact strength, Izod, –40°F.	2.0	FT.-LB./IN.	D256-47T
73°F.	4.0	FT.-LB./IN.	D256-47T
Stiffness, 73°F.	60,000	LB./SQ. IN.	D747-48T
Flexural strength, 73°F.	did not break		D790-49T
Compressive stress at 1% deformation	670	LB./SQ. IN.	D695-49T
Creep in flexure	67		*
Hardness, Rockwell	D55		**

THERMAL:

			METHOD
Coefficient of linear thermal expansion per °F.	5.5×10^{-5}		D696-44
Thermal conductivity	1.7	B.T.U./hr./sq. ft./°F./in.	***
Specific heat	0.25		—
Deformation under load, 122°F., 2000 lb/sq. in.	25	%	D621-48T
Heat-distortion temperature, 264 lb/sq. in.	140	°F.	D648-45T
66 lb/sq. in.	270	°F.	D648-45T

ELECTRICAL:

			METHOD
Dielectric strength, short-time	480	V/MIL	D149-44
step-by-step	430	V/MIL	D149-44
Volume resistivity	$> 10^{15}$	OHM-CM.	D257-49T
Dielectric constant, 60 cycles	2.0		D150-47T
10^3 cycles	2.0		D150-47T
10^6 cycles	2.0		D150-47T
10^8 cycles	2.0		D150-47T
Power factor, 60 cycles	< 0.0005		D150-47T
10^3 cycles	< 0.0005		D150-47T
10^6 cycles	< 0.0005		D150-47T
10^8 cycles	< 0.0005		D150-47T

OPTICAL:

Index of refraction	1.35	n_D	D542-42

MISCELLANEOUS:

Water-absorption	0.0	%	D570-42
Flammability	nonflammable		D635-44
Specific gravity	2.1-2.3		D792-48T
Resistance to weathering	excellent		
Basic color	light opaque		

*Term "creep in flexure" is a measure of the deformation under a prolonged standard load. Results here represent mils deflection in 24 hrs. of a ⅛" x ½" bar, 4" span, center-loaded flatwise to 1,000 lb./sq. in., minus the initial deflection.

**Hardness of "Teflon" determined by Shore durometer, A.S.T.M. method D676-49T.

***Thermal conductivity measured by Cenco-Fitch apparatus.

Note: This table shows the typical property data for Du Pont "Teflon" TF-1.

E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Department,
Room 365 Du Pont Bldg., Wilmington 98, Delaware.

Please send me more information on Du Pont "Teflon" tetrafluoroethylene resin: Uses ☐; Processing Techniques ☐; Properties ☐. I am also interested in receiving more information about Du Pont nylon resins ☐; "Alathon" polyethylene resin ☐; "Lucite" acrylic resin ☐.

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50 AND 100 YEARS AGO

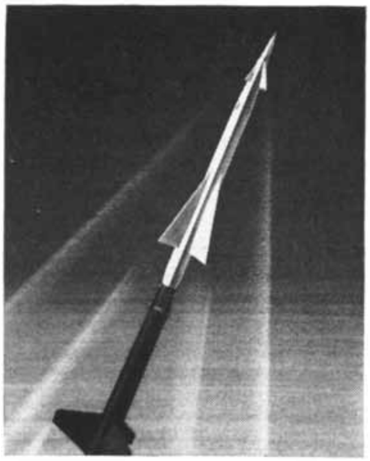
SCIENTIFIC AMERICAN

MAY, 1904: "In a recent address before the Michigan Municipal League, Dr. Victor C. Vaughn estimated the annual loss in this country due to typhoid fever at $50,000,000. He said the total number of cases of this disease in the course of the year was about 500,000, of which 50,000 terminated fatally. Placing a valuation of $1,000 on each life, he arrived at the total given above. The doctor said that this terrible death list should have no existence, for by the exercise of proper care and precautions, all of these lives might be saved."

"What will unquestionably be the greatest automobile event of the year in this country is the run to the St. Louis Exposition, which is planned for the latter part of July. The intention is to have motorists from all parts of the country make a triumphal entry into St. Louis on the same day, which will probably be Thursday, August 11. The various routes are all being investigated, and full information concerning them will soon be obtainable from the American Motor Association."

"Word has been received from England of the death on May 10 of that great African explorer and colonizer Henry Morton Stanley. Following the lead of Livingstone, in relieving whom he first started to explore the dark continent in 1871, Stanley spent the best years of his life traveling through tropical jungles and tracing out lakes and rivers in the very heart of Africa, and to him is due the credit for solving her most puzzling geographical problems."

"The latest accident report of the Interstate Commerce Commission opens with a statement of the number of killed and wounded on the railroads of the United States during the last quarter of 1903. We give the opening sentence of the report in the exact words in which it describes what is at once a supreme national tragedy and an abiding national disgrace: 'The number of persons killed in train accidents during the months of



TELEPHONE SCIENCE GUIDES A PUNCH NO ENEMY CAN DODGE

(Upper left) — Nike's missile climbs to destroy an enemy, under guidance of complex electronic controls. A radar is shown at right. Nike (pronounced Ny'kee) is named after the Greek goddess of Victory.

BELL TELEPHONE LABORATORIES

Is it possible to guide an anti-aircraft missile so that it will track down and destroy a rapidly maneuvering target? No one knew the answer for sure when the U. S. Army put this question to Bell Telephone Laboratories in 1945.

The special skills and techniques developed to create the nation's communications network uniquely fitted Bell scientists to answer this question. They recommended a new system, Nike, and then worked to bring it into being with engineers from Army Ordnance, Western Electric Company and Douglas Aircraft Company.

The first Nike installation has been made, and more will follow. Thus, America's defenses grow stronger through a new extension of frontiers in the communications art. It is a proud achievement of the knowledge and skills first developed at Bell Telephone Laboratories to make the nation's telephone service ever better.

Improving telephone service for America provides careers for creative men in scientific and technical fields

October, November and December, 1903, as shown in reports made by the railroad companies to the Interstate Commerce Commission, under the "Accident Law" of March 3, 1901, was 446, and of injured, 3,178. Accidents of other kinds, including those sustained by employees while at work, and by passengers in getting on and off the cars, etc., bring the total number of casualties up to 14,485, or 1,166 killed and 13,319 injured.' "

"Sir Norman Lockyer and his son have communicated to the Royal Society a paper in which they show a connection between solar prominences and terrestrial magnetism. The occurrence of magnetic 'storms' on the earth is proved to depend on some cause that also affects the frequency of solar prominences."

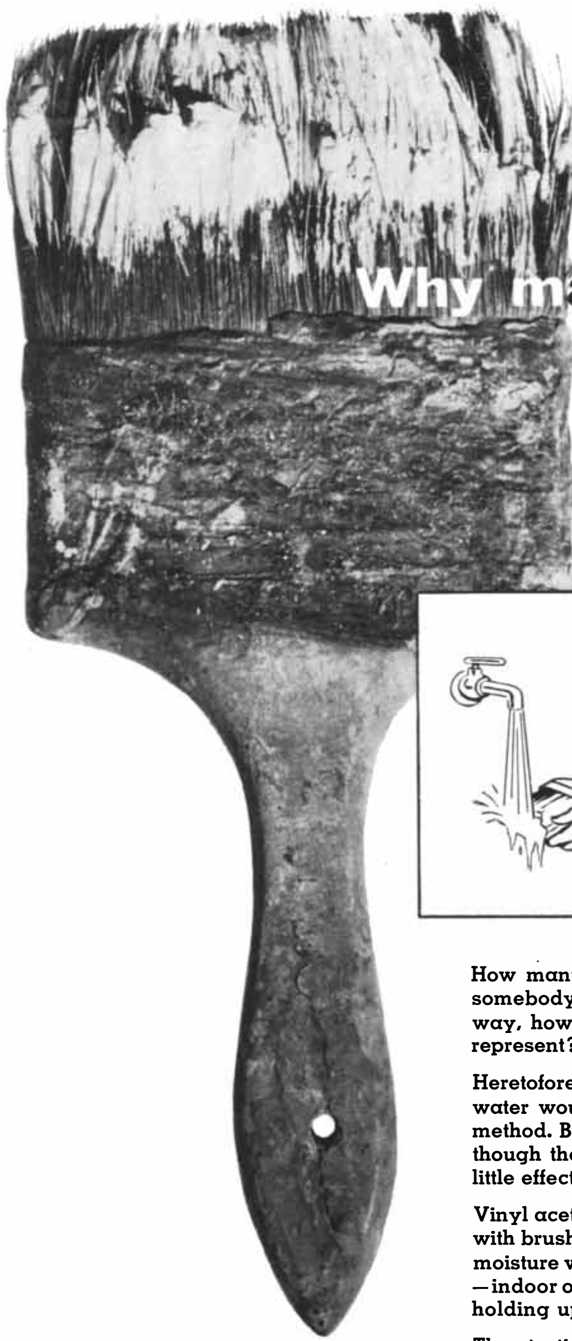
SCIENTIFIC AMERICAN

MAY, 1854: "At Marseilles, France, recently a Dr. Payerne descended with three sailors in a machine of his own invention, and, after remaining under water a considerable length of time, climbed into the port-holes of a man-of-war in the harbor without being perceived by the crew."

"Prince Paul of Württemberg is now in this country collecting botanical and ornithological specimens for the publication of a work when he returns to Europe. This is a very creditable occupation for a Prince, and it would be more to the honor of them all if they engaged in some such useful and instructive profession."

"Although gas made from coals is coming into more general use, in our cities, &c., thus doing away with the necessity of using oil, still the demand for oil is becoming greater every day. Enormous quantities of it are now being used on all our railroads for lubrication, thus entailing a great working expense on such systems of travel. Therefore any improvement to increase the quantity of the oil, improve it, or render it cheaper, becomes of great importance to the community—for the people pay for all these things."

"Meteorites are not of terrestrial origin. The number of those who think that they are is too limited to require a set refutation of that theory. They are



Why many painting projects are never started

Easy brush cleaning is one of the reasons why Vinyl Acetate Water Based Paints promise to be popular with everyone

How many home painting projects are stopped in their tracks because somebody forgot to clean the paint brushes the last time? To put it another way, how many lost sales of paint does the problem of brush cleaning represent?

Heretofore, most paints that could be washed out of brushes with ordinary water would eventually be "washed off" painted surfaces by the same method. But the new vinyl acetate paints exhibit sturdier properties. Even though they are water based, when once dry, water and moisture have little effect on them.

Vinyl acetate paints can be called "one coat" paints. They can be applied with brush, roller or spray and dry in minutes. Best of all, they're porous to moisture vapor, which means they can be used on fresh plaster and stucco —indoor or out. Original applications of these paints ten years ago are still holding up.

The starting point of these new paints is vinyl acetate monomer—fundamental chemical now produced in volume from selected petroleum gases by Celanese. It is converted into resin emulsions by other processors who supply the product to paint manufacturers. Celanese large scale production has been a major factor in stabilizing the price of this chemical and helping to make these new paints competitive in every application. Would you like to know more about the myriad industrial applications for vinyl acetate monomer? They embrace the textile, adhesives, coatings, paper and soil conditioning fields. Write for descriptive folder.

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CHEMICAL PROGRESS WEEK—MAY 17-22

Celanese* CHEMICALS

not of atmospheric origin, aggregated from different directions, hardened like hail, though from different causes. Their form forbids that suspicion. Whence then are they? In a paper on the subject given at the meeting of the American Association for the Advancement of Science, Dr. Lawrence Smith accepted the 'lunar theory,' that meteorites are masses thrown off with great force from the moon, revolving around that body until, in the great eccentricity of their orbits, they fall within the circle of our atmosphere, once within which our earth becomes their center. They may have been thrown out from the craters of volcanoes a long time ago, and been thousands of years revolving before their orbit brought them into contact with our sphere. Laplace and Arago, who once held this theory, gave it up, but they were compelled to do so or surrender another belief of theirs, that they are identical with shooting stars."

"One of the greatest discoveries of our day, says a French paper, is that made by Claude Bernard of the constant formation of sugar in the liver of animals. Feed an animal how you will—with food containing saccharine matters, and with food containing no trace of them—you always find the animal has formed sugar for itself. This sugar, which is secreted by the liver, is, like all secretions, under the influence of the nervous system; you have only to cut what are called the pneumogastric nerves and in a few hours all the sugar vanishes."

"Professor Henry of the Smithsonian Institution read an able paper on architecture at the meeting of the American Association for the Advancement of Science. He said: 'Architecture should be looked upon more as a *useful* than a *fine* art. It is degrading the fine arts to make them entirely subservient to utility. It is out of taste to make a statue of Apollo hold a candle, or a fine painting stand as a fire-board. But our houses are for *use*, and architecture is substantially one of the useful arts. In building we should plan the inside first, and then plan the outside to cover it. Buildings should have an ethnological character. They should express to other ages the wants, customs and habits of the age of their construction. A Grecian temple was intended for external worship. An old Greek would laugh to see us construct a Grecian temple for a treasury building or a meeting house. It should have no windows in it, and should be entirely too dark for such uses. But it is easier to copy than to originate, and hence our servility.' "

So terrifyingly powerful is Cobalt 60—radio-active offspring of the atom bomb and great new weapon in the fight against cancer—that a single spoonful produces as much radiation as all the radium in the world.

And Cobalt 60 is but one of many radio-active isotopes, spawned by the Atomic Age, that offer benefits and advances in medicine, industry and agriculture. Realization of these promises depends in part on development of economical and versatile materials for shielding the "hot" isotopes.

One such material is Mallory 1000 Metal, a high density alloy of tungsten, nickel and copper that has already proved itself a highly effective shield for "containing" deadly radiation.

Requiring far less space than other shielding materials, Mallory 1000 also is easily machined to almost any size or shape and thus lends itself to a wide range of applications . . . storage containers for isotopes . . . reactor shields . . . oil well loggers . . . medical equipment . . . many kinds of meters and instruments.

Because of its high density and machinability, Mallory 1000 is widely used in gyroscope rotors and in counterbalances where great weight is required in small space.

It is a unique and versatile product—typical of the precision quality of all Mallory products in the fields of electronics, electrochemistry and specialized metallurgy.

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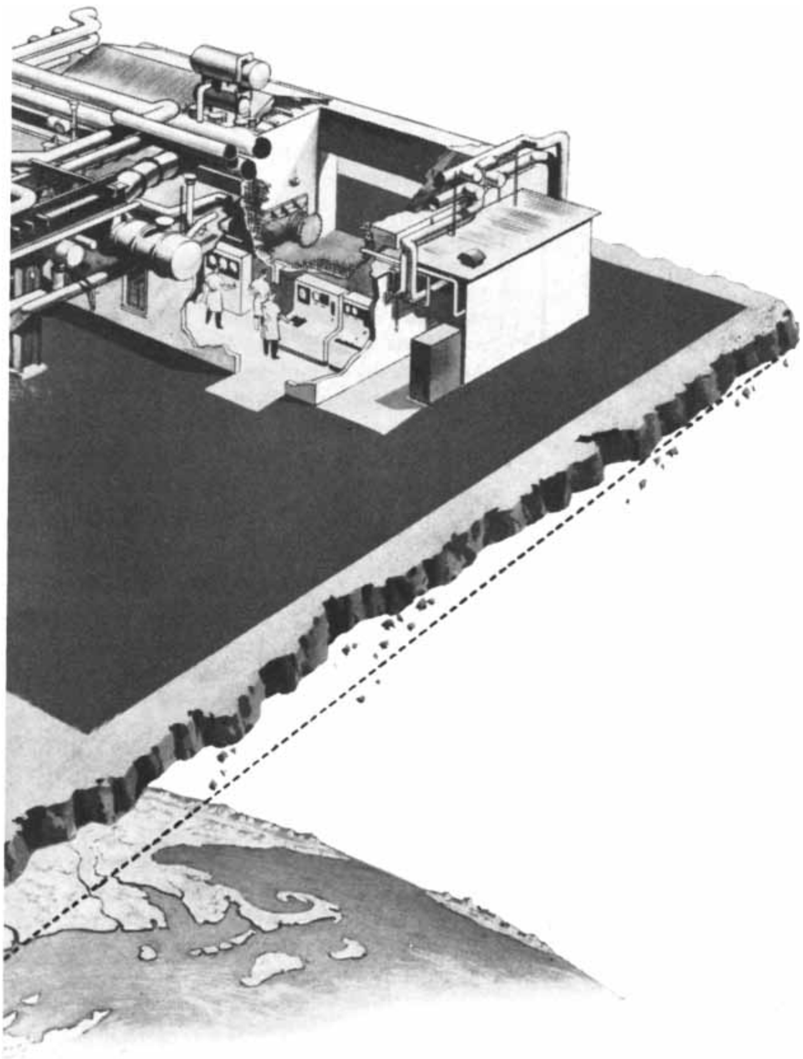

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This is just a little bit of Bendix in the aviation field. You should get the full story of Bendix Aviation Corporation and how it can contribute to your business. Our product line and technical abilities are so diverse that we're certain you'll find specific uses for improving most any type operation. We're developing new products and new techniques constantly. We invite you to follow through on the following suggestion:

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Stromberg carburetors, electric fuel pumps, starter drives, coaster brakes.*

BENDIX PRODUCTS, SOUTH BEND, IND.
automotive brakes, carburetors, power steering; aviation brakes, landing gear, fuel metering.

SCINTILLA, SIDNEY, N. Y.
aviation ignition systems; industrial engine magnetos; diesel fuel injection.

BENDIX RADIO, TOWSON, MD.
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meteorological instruments; precision instruments and recorders.

RED BANK, EATONTOWN, N. J.
electronic tubes; dynamotors, inverters.

ZENITH* CARBURETOR, DETROIT, MICH.
automotive, marine and small engine carburetors.

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micronic filters.

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telemetering equipment; hydraulic and electric actuators; depth recorders; boat steerers.

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automatic viscosity regulators, nuclear products.

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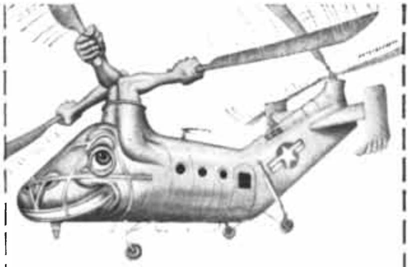
THE AUTHORS

ANGUS CAMPBELL ("The Electoral Switch of 1952") is director of the University of Michigan's Survey Research Center, which conducted a broad study of the 1952 Presidential election. His comprehensive report on the study is being published this month as a book entitled *The Voter Decides*. An article by Campbell, Gurin and Miller on the role of television in the 1952 election appeared in the May, 1953, issue of this magazine.

SYDNEY CHAPMAN ("Tides in the Atmosphere") is a mathematician, astronomer and geophysicist. He was born in Manchester, England, in 1888. After studying engineering at Manchester University, he did graduate work in mathematics at Manchester and at Cambridge. He was an astronomer at the Greenwich Observatory for a few years, returned to Cambridge as a fellow and lecturer in mathematics and later was professor of mathematics at Manchester, the University of London, and Oxford. During World War II he served as deputy scientific adviser to the British Army. Since 1951 he has been advisory scientific director and visiting professor of geophysics at the University of Alaska. He is at present a visiting lecturer at New York University. Chapman is a fellow of the Royal Society, a past president of the Royal Meteorological Society and of the Royal Astronomical Society. Currently he is serving as president of the International Union of Geodesy and Geophysics and of the International Commission for the International Geophysical Year. A much-traveled man, Chapman has toured many parts of the world, "on foot, by cycle and by air."

J. B. BIALE ("The Ripening of Fruit") started out to be a scientific farmer, but science proved more interesting than farming and he decided to devote his career to understanding plants rather than to growing them. He was born in Poland in 1908, came to the U. S. at the age of 20 and registered at the Agricultural School of the University of California. Knowing no English, he found a Polish-English dictionary "the most indispensable companion in freshman botany." He went on to take his Ph.D. in plant physiology and joined the faculty of the University of California at Los Angeles, where he is now

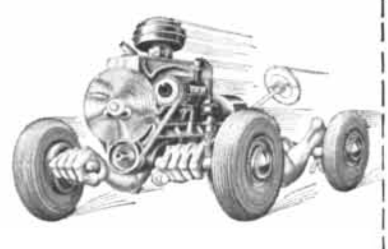


How a helicopter hangs by its "elbows"

For flexible "elbows"—625-part rotor assemblies that control the amazing maneuvers of its dependable H-21 "Work Horse" Helicopter—PIASECKI *looks to Lycoming!*

How a jet engine runs on its "nerves"

To produce the auxiliary "nerve center" for its J-40 jet engine—a complex gearbox that transmits power to vital engine accessories—WESTINGHOUSE *looks to Lycoming!*



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For vital automotive parts—mass-produced precision components that can "take it" year after year—leading automobile manufacturers like FORD *look to Lycoming!*

Strong "wrists" for America's new hay balers

For sturdy, dependable spur and bevel gears—"wrists" that drive the tying mechanism of its "one-man" time- and money-saving hay baler—NEW IDEA *looks to Lycoming!*

"Leg muscles" that cushion a jet's landing

For tough main leg cylinders that house the hydraulic action which enables the F-86 Sabrejet to absorb fast landing jolts—CLEVELAND PNEUMATIC *looks to Lycoming!*

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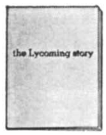
If you need dependable parts . . . or any other diversified services listed with our signature . . . call us without obligation. Lycoming's wealth of creative engineering ability, its 2½ million square feet of floor space, and 6,000-plus machine tools stand ready to serve you. *Whatever* your problem . . . *look to Lycoming!*



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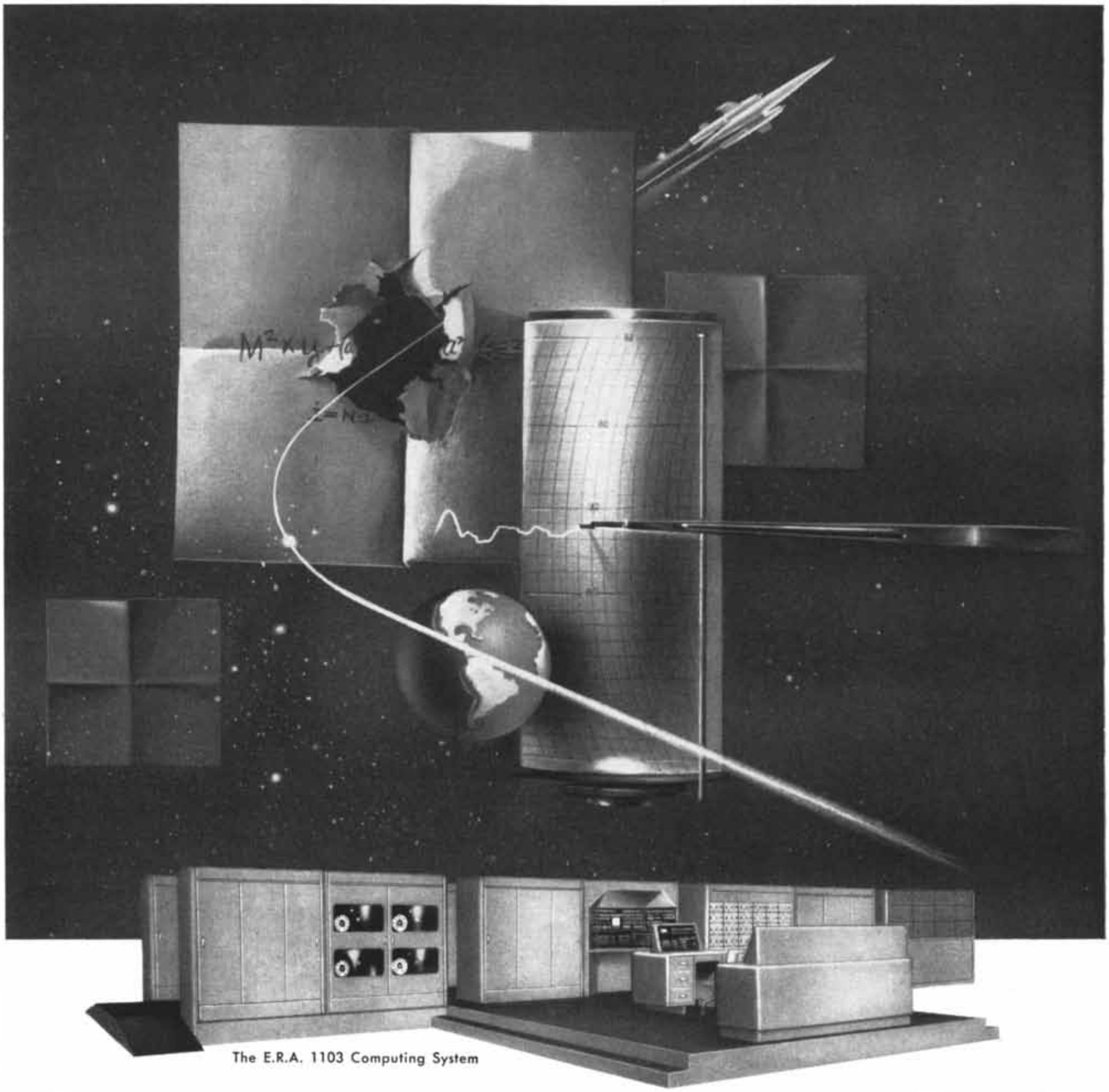
associate professor of horticulture. His chief research interests are in the fields of plant respiration and fruit physiology. Biale's spare time is divided between handball, tennis, skiing and his three children. Of his adopted country he says, "the U. S. A. in general and California in particular afforded me the opportunities denied elsewhere for a full and rich life, for which I am deeply grateful."

GEORGE E. HENRY ("Ultrasonics") can treat sound waves as a musician and as a physicist. Born in Jacksonville, Fla., in 1911, he attended the Engineering College of the University of Florida for a year but left it to go to the American Conservatory of Music. There he studied composition and conducting and played the cello in the Chicago Civic Orchestra. Ten years as a music teacher and professional cellist followed. He was assistant professor of music at the Woman's College of The University of North Carolina when, in 1943, he felt a wartime call to return to physics. He taught physics and electronics to naval officer candidates at the University of North Carolina. After the war he accepted an assistant professorship of music at Vassar College. Hearing that the General Electric Company was doing new work in sonics at its Schenectady laboratory, Henry seized the opportunity to combine his interests in sound and in physics. As a development engineer at G. E. he designs special equipment ranging from computers for statistical quality control to ultrasonic cleaning machines.

ROBERT M. INGLE ("The Life of an Estuary") heard the call of the sea from a thousand miles away. Born and brought up in Danville, Ill., he majored in biology as an undergraduate at the University of Illinois and took graduate work there and at other Midwestern universities. In 1946 he went to the University of Miami in Florida to round out his biological training with some salt-water studies. He stayed to teach at Miami and to work in the marine waters off the east coast of Florida and in the Gulf of Mexico. At present Ingle is senior research assistant at the marine laboratory of the University of Miami and assistant editor of the *Bulletin of Marine Science of the Gulf and Caribbean.*

JOTHAM JOHNSON ("The Language of Homer's Heroes") is chairman of the classics department at the Washington Square College of New York University. He was born in Newark,



The E.R.A. 1103 Computing System

N. J., in 1905 and educated at Princeton University, the University of Pennsylvania and the American School of Classical Studies in Athens. His archaeological studies have taken him to Greece, Syria and Italy. From 1931 to 1934 he was field director of the University of Pennsylvania Museum excavations at Minturnae, Italy; later he taught at the University of Pittsburgh. During World War II he was a lieutenant commander in the Navy. Since 1946 at N. Y. U. he has indulged an appetite for interpreting classical studies to non-professionals. He founded *Archaeology,* the first magazine published by a learned society for a popular audience, and was its editor for four years. In 1950 Johnson was Norton Lecturer of the Archaeological Institute of America and in the last academic year he held a Fulbright Research scholarship at the University of Rome.

H. HEDIGER ("Are Wild Animals in Captivity Really Wild?") is director of the Zoological Garden in Zurich, Switzerland. He decided that he wanted to run a zoo at the age of five. Hediger was born in Basel in 1908. As a boy he spent every spare moment in the woods and maintained a considerable menagerie in his cellar, to his parents' horror. He studied zoology, botany and psychology in Swiss universities but found no courses in the subject that interested him most—animal psychology. He therefore studied it on his own. In the course of his self-training he traveled extensively in Africa and in the South Pacific. He became curator of the zoological division of the Basel University Museum, and at length in 1937 was offered the directorship of a small zoo in Bern. He took over at Zurich this year. Hediger finds that scientific zoo-keeping requires taking into account "all the life phenomena of the zoo, from the parasites of the exhibited animals to the psychology (psychopathology) of the visitors." Man, he says, can learn a lot about himself in a zoo.

SIR EDMUND WHITTAKER ("William Rowan Hamilton"), still active at the age of 81, has spanned several generations of British science in his long career. His last previous article for SCIENTIFIC AMERICAN, appearing in November, 1953, was a biographical sketch of G. F. Fitzgerald, whom he knew personally. From 1906 to 1912 Whittaker occupied the same chair of astronomy at Dublin that had been held by the subject of whom he writes affectionately in this article.

Advances in Applied Radiation

DEVELOPMENTS in the FIELD OF APPLIED RADIATION ENERGY, its APPLICATIONS and the APPARATUS USED TO PRODUCE IT

Radiation Facilities at High Voltage

The versatility of today's accelerators is demonstrated by the radiation power available to industry for experimental and process work at HIGH VOLTAGE's plant in Cambridge:

- Electron energies up to 2.25 MeV capable of delivering dosages of ionizing power up to 50 million gram rep per second — two hundred times greater than the *hourly* output of a kilocurie source of Cobalt. Our Van de Graaff facility can completely sterilize samples at rates up to 200 gross pounds of material per hour, or can deliver massive radiation doses to plastics or chemical systems on a continuous process basis.
- X-ray intensities up to 300 roentgens per minute at 50 cm. Both 1- and 2-million-volt x-rays are available for radiography or research.
- Positive ions (both protons and deuterons) in the range from 0.75 to 2.0 MeV at continuous beam currents up to 50 microamperes.
- Thermal neutron fluxes up to 5×10^8 n/sec-cm^2.
- Monoenergetic neutrons from the kilovolt range up to 6 MeV.

Three accelerators in our plant are being used on a contract basis by major industrial companies. We believe these facilities are unmatched in the world today.

The Superiority of Particle Accelerators as Radiation Sources

As a company whose business is the practical application of radiation energy, it is HIGH VOLTAGE's job to investigate alternative sources of this energy — nuclear reactors, pile-produced radioactive sources, and the by-products of nuclear fission — as well as the particle accelerators. *For most applications, including research, the superiority of machine radiation sources is startling.*

Radioactive sources in the multi-megacurie range would have to be available at a cost, including shielding and transportation, of a few cents per curie before the power capabilities and costs of the accelerators *available today* could be matched for commercial use. Even in experimental research, electron sources have become a practical necessity where dynamic systems requiring high dose rates are involved. The very low output and absorption of gamma radiation from radioactive isotopes makes it impossible to produce useful yields in a reasonable period of time.

Long recognized as precision sources of a wide range of monoenergetic neutrons for research, today's Van de Graaff particle accelerators are also capable of producing, with virtually no gamma background, neutron fluxes which match those available at the experimental portals of large nuclear piles. Neutron fluxes of 10^{10} n/sec-cm^2 over a sphere of 10 cm in diameter appear feasible with today's accelerator technology, with equipment costs which are a fraction of those associated with the construction of a nuclear reactor.

This is an electron-
a negative personality but usually
very fast.

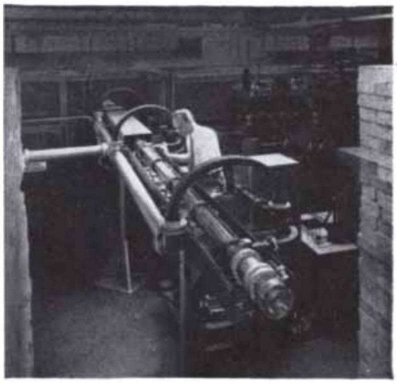
New Tool for the Oil Industry

HIGH VOLTAGE's Model HN 0.5-million-volt Van de Graaff is now being used by Well Surveys, Inc., Tulsa, Oklahoma, in studying the scattering characteristics of radiation in soil strata.

Well logging has become increasingly important in oil-well exploration, and today nearly all rotary-drilled wells are logged at least once before completion. Of all available techniques of logging, radioactivity logging, developed by Well Surveys, Inc., has proved to be the only method of locating and identifying subsurface formations in both open and cased holes. In the past, research in scattering characteristics has been carried out with radioactive isotopes, but these have lacked both the necessary intensity and the desired energy. Well Surveys' new Van de Graaff can produce a flux of neutrons as great as that from several hundred grams of radium-beryllium. With this compact accelerator, Well Surveys expects to gain more precise data for increasing the efficiency of oil-well completion and exploitation.

New Linear Accelerator

HIGH VOLTAGE has delivered the first microwave linear accelerator to be built commercially in the United States. Combining radar and accelerator techniques, this unit is controllable in energy from 10 to 50 million volts, and will be used to study the effectiveness of direct high-energy electron bombardment in cancer treatment. Completely engineered by HIGH VOLTAGE, it is based on designs of the Microwave Laboratory, Stanford University, and employs klystron amplifier tubes and wave guides developed and constructed at Stanford.



Radar pulses from the klystrons carry bursts of electrons along the 16-foot wave guide in which a very high vacuum is maintained. At the end of the guide, the electrons have attained a speed nearly equal to that of light and weigh 100 times more than when they started. A thin aluminum window maintains vacuum in the wave guide and allows the electron beam to be used externally in cancer-treatment research.

With the successful completion of this apparatus — the first linear accelerator for medical use in this country — HIGH VOLTAGE has added both a new product and a new technology to its versatile line of accelerators for medicine, research, and industry.

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Look What's Happening In

Metals

THE MOST FABULOUS SUPPLY OF ELECTRIC POWER IN THE WORLD FLOWS TO U. S. HOMES, FARMS, AND FACTORIES . . . AND TO HELP CARRY THE LOAD, ANACONDA MAKES A COMPLETE LINE OF WIRE AND CABLE

Last year our homes, farms and factories soaked up nearly *400 billion* kilowatt-hours of current.

That's twice as much as 10 years ago.

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From seven strategically located mills of the Anaconda Wire & Cable Company, the electrical industry has been able to shop for its many wire needs...from hair-thin magnet wire to fist-thick power cables.

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Behind every foot of Anaconda wire and cable stands a *fully integrated* business, modern in its methods and equipment. It links the resources of many mines and plants. That's why Anaconda and its subsidiaries are able to serve you so well with such a wide diversity of products. 54274

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PRODUCERS OF: Copper, zinc, lead, silver, gold, platinum, cadmium, vanadium, selenium, uranium oxide, manganese ore, ferromanganese and superphosphate.

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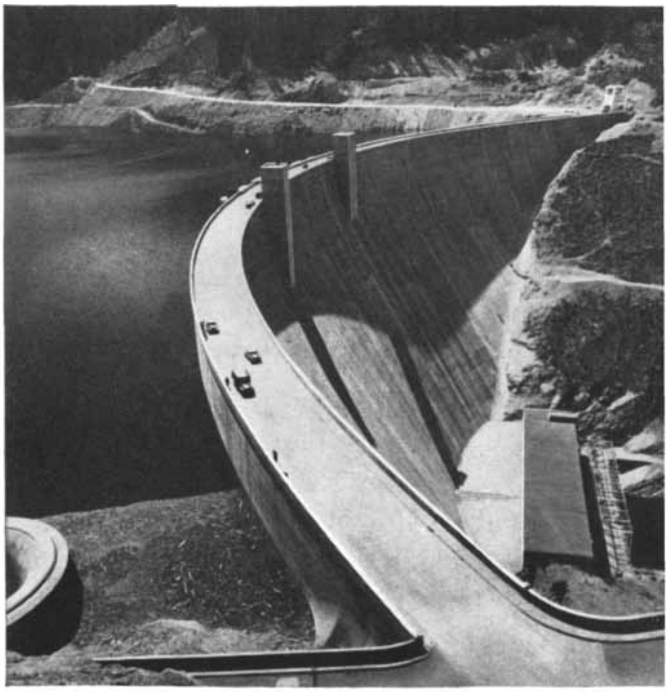
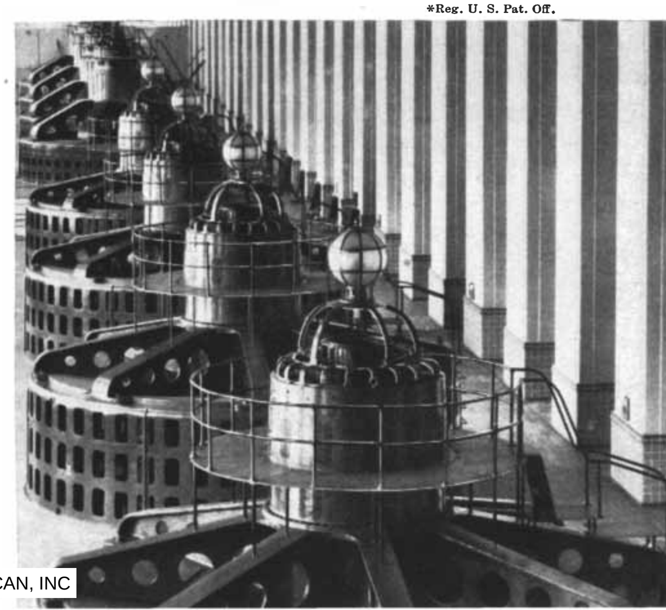
◀ **PATROLS REGULARLY CHECK** every mile of transmission line for America's light and power companies — on foot . . . in jeeps . . . in boats . . . and, fastest of all, in helicopters that hover a few feet over the cables. For these are the nerves of a nation, sometimes copper and, where they must be light in weight, sometimes aluminum. Anaconda supplies both types of cables to the nation's leading electric companies.

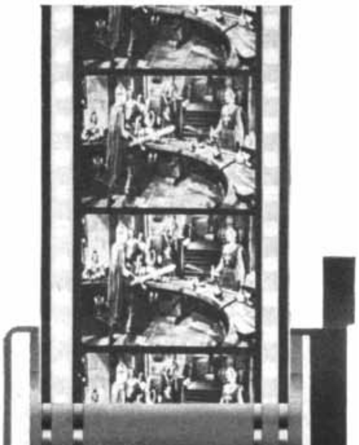


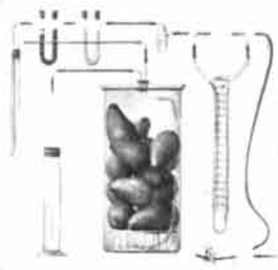
HUNGRY HORSE DAM will supply the power for Anaconda's new aluminum reduction plant now being built at Columbia Falls, Montana. Every ton of finished metal will take some 18,000 kilowatt-hours of current. Production starts late in 1954. Then 52,000 tons a year will help supply the growing market for this lightweight metal.

WHAT DO YOU NEED TO MAKE ELECTRICITY? A source of power, of course. This may be fuel or flowing water. Next—turbines and generators must convert this power into usable electricity. For many years The American Brass Company, an Anaconda subsidiary, has supplied corrosion-resistant parts for these turbines and generators, tubes for steam condensers, bus conductors for switchgear, and Everdur* Electrical Conduit to protect wires and cables against corrosion and physical damage.

*Reg. U. S. Pat. Off.







THE COVER

The painting on the cover depicts an apparatus for measuring the amount of carbon dioxide generated by ripening avocados (*see page 40*). Compressed air is admitted to the apparatus through the small tube at the lower right. The air, its flow kept constant by the flow meter at right and the brass bleeder valve below it, proceeds to the two U-tubes at the upper left. The first of these contains calcium chloride, which removes water vapor from the air so that it does not enter the second. The second U-tube contains Ascarite, which removes carbon dioxide from the air. The air is now bubbled through water in the test tube at the left to restore its water-vapor content. Finally it is conducted into the large vessel in the center. The air which leaves the vessel is bubbled through a solution of sodium hydroxide at the lower left. After this solution is bubbled for about half an hour, its acidity is measured. The acidity is proportional to the amount of carbon dioxide generated by the avocados.

THE ILLUSTRATIONS

Cover by John Langley Howard

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DESIGNING WITH ALUMINUM

This is one of a series of information sheets which discuss the properties of aluminum and its alloys with relation to design. Extra or missing copies of the series will be supplied on request. Address: Advertising Department, Kaiser Aluminum & Chemical Sales, Inc., 1924 Broadway, Oakland 12, California.

NO. 7

ALUMINUM FOR DUCTS

NEW RESEARCH DATA SHOWS ALUMINUM PROVIDES REDUCED HEAT AND FRICTION LOSSES

In No. 2 of these information sheets on Designing With Aluminum, which dealt with some of aluminum's thermal properties, mention was made that bare aluminum ducts were more efficient than bare galvanized or metal ducts covered with asbestos paper in delivering hot or cool air. This results from the fact that one of aluminum's useful properties is high reflectivity to radiant energy, and corresponding low emissivity.

Recent research studies by F. W. Hutchinson of Berkeley, Calif., have demonstrated that friction losses in aluminum ducts are substantially less than in galvanized ducts. This means that for the same duct size aluminum will require less power, and hence permit lower operating costs. Or, for the same friction loss, the aluminum duct will be of smaller diameter, thus providing for possible savings both in first cost and through more effective use of building space.

Duct Size Reduced By Using Aluminum

The new data have definite practical significance, as shown in Figure 1. This has been prepared for a heating system using bare aluminum duct with hot air in at 170°F and 100 feet of duct running through a space in which the ambient temperature is 60°F. It combines the influence of reduced friction loss and reduced heat transfer, and shows that substantial savings in duct size can be obtained through the use of aluminum.

The influence of heat loss (or gain in the case of air conditioning) is most important in small diameter ducts with low air velocities, while friction loss has the greatest significance in small ducts at high velocities. The result is that for small to moderate size ducts there is a saving in diameter of from 5% to 12% over the entire range of velocities.

Consider, in Figure 1, the use of a 6″ duct with 700 feet per minute velocity: for these operating conditions the bare aluminum duct would be 12% smaller than an asbestos-paper covered galvanized duct. This means that the aluminum duct would handle a smaller volume of air to deliver equal heat at the point of discharge. Further, the velocity in the aluminum duct would exceed that in the other duct, but the loss in head would be the same.

Since the power requirements of an air distribution system depend on volume and head loss, it is evident that in this instance the bare aluminum duct would not only be 12% smaller, but would provide additional saving through lower operating power requirements.

In a series of actual tests it has been determined that the absolute roughness of aluminum duct is about one-third that of galvanized, on the order of 0.00015 to 0.0005. Friction charts developed directly for aluminum show, in comparison to friction charts for galvanized, a reduced friction loss which varies in amount with velocity and with duct diameter.

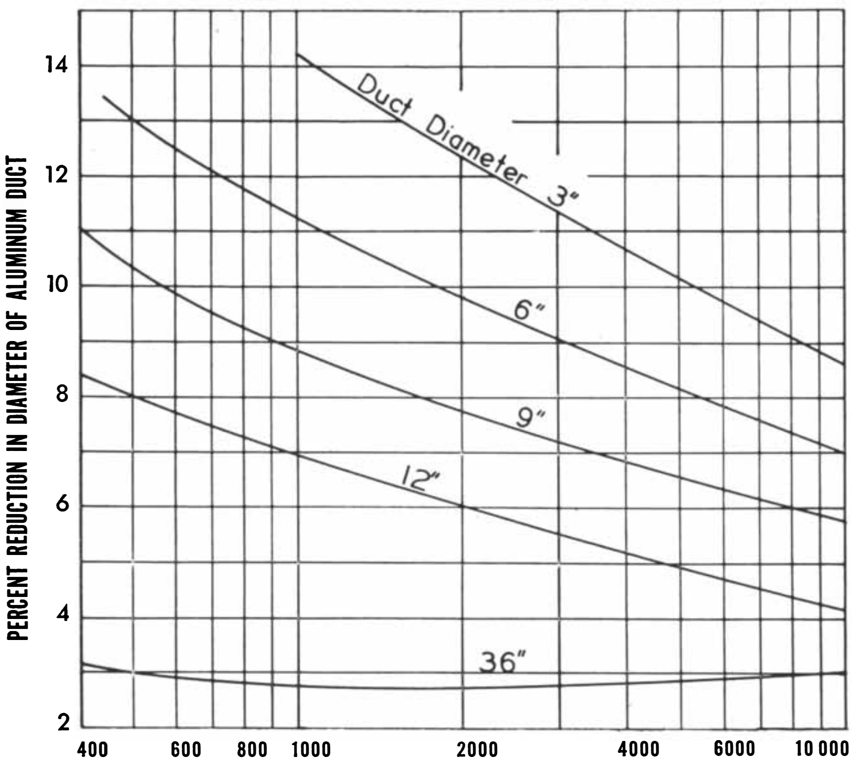

Fig. 1

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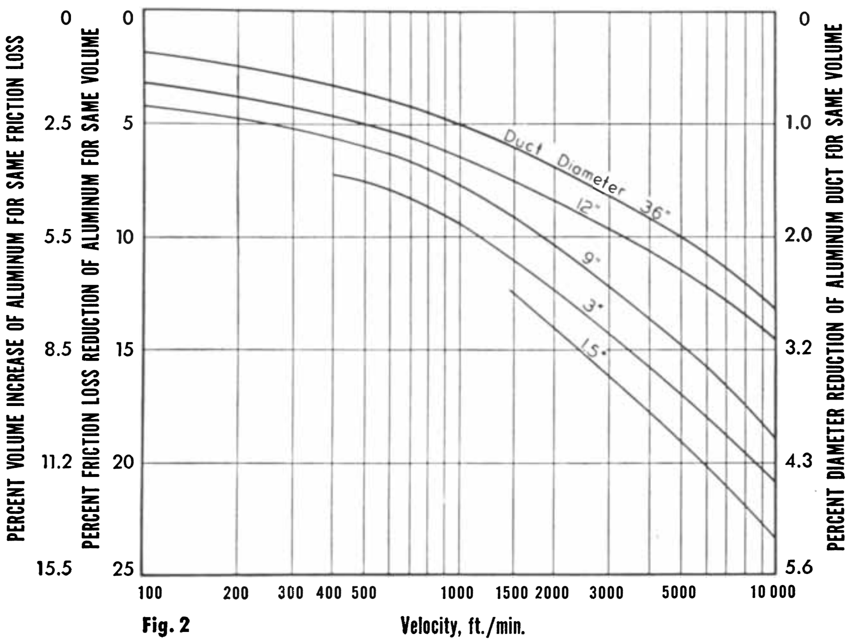

Fig. 2

Friction Most Important At High Velocities

For large ducts at low velocity the reduction in head loss is a few per cent, but small aluminum ducts at high velocity will afford savings in friction loss of 20% and over. This advantage of aluminum is of special significance in view of the increasing trend toward small high-velocity duct systems.

For systems used purely for ventilation or exhaust purposes, where the supply air is neither heated nor cooled, the reduction in size of aluminum duct, as compared with galvanized, is due entirely to the lesser friction loss. Figure 2 provides a means of comparing the two duct materials over a wide range of diameters and velocities, and permits the designer also to determine directly and exactly the comparative advantages of aluminum for any particular duct.

The scale at the far left in Figure 2 gives the per cent increase in volume which can be passed through an aluminum duct for fixed value of the friction loss; this volume increase would permit a corresponding reduction in diameter as given on the scale at the far right. In cases where it is not desirable to reduce the diameter, the aluminum duct would provide a reduction in friction loss as indicated on the inner scale at the left.

For example, a 9″ diameter aluminum duct carrying air at a velocity of 4000 feet per minute would have a friction loss approximately 13½% less than a corresponding galvanized duct. For the same friction loss the aluminum duct would carry approximately 7½% more air, and would be approximately 3% smaller.

A 32-page report, "The Design of Aluminum Duct Systems," has been prepared for Kaiser Aluminum by Mr. Hutchinson on the basis of the new data. It presents for the first time a design procedure, including graphical methods, directly and uniquely applicable to aluminum ducts.

Among the charts included in this book are charts giving friction loss per 100 ft. in aluminum ducts as a function of velocity, volume and diameter. They are similar to those which have been regularly used in connection with galvanized installations, but are developed especially for aluminum. Thus they enable the engineer to design directly for aluminum and avoid the necessity for the use of approximate conversion factors.

Copies may be obtained without cost by writing Kaiser Aluminum at 1924 Broadway, Oakland 12, Calif., or through any of the company's sales offices in principal cities of the country.

Additional Aluminum Advantages

The lower heat and friction losses discussed above are not the only advantages to be derived from the use of aluminum duct work in heating, ventilating and air conditioning systems. Aluminum's corrosion resistance contributes to long life and minimum maintenance. Moisture does not cause red-rusting or stains. Its workability and light weight provide for reduced fabrication and installation costs. General practice calls for equal thickness of metal, whether aluminum or galvanized, in duct installations.

Although the advantages of aluminum in this type of application are naturally of most interest to heating and ventilating engineers, architects and those concerned with the construction and operation of buildings, they also provide an outstanding illustration of how aluminum's unique combination of properties make it one of the world's most useful and versatile metals. Assistance or information on individual application, fabrication procedures and the selection of alloys and forms of aluminum may be obtained on request.

SCIENTIFIC AMERICAN

Established 1845

CONTENTS FOR MAY, 1954 VOL. 190, NO. 5

ARTICLES

DEPARTMENTS

Here's the fastest way to make honeycomb panels

This assembly line's speed brings the cost of making honeycomb sandwiches way down. It uses an air-drying adhesive that's designed especially for fast assembly-line bonding, Armstrong's D-253 Adhesive.

The process takes less than two minutes. D-253 is applied automatically to core and skin sheets on conveyors. Infrared heat dries the adhesive uniformly. After assembly, one run through a pressure roll finishes the job. D-253 bonds upon contact, needs no curing.

This Armstrong's Adhesive bonds all types of skins, including stainless steel, aluminum, wood, plastic laminate, and paper. With D-253 you can produce strong, lightweight panels for a wide variety of uses such as table tops, flush doors, and interior partitions.

An Armstrong adhesives specialist will be glad to help you work out plans for honeycomb production. Just call or write Armstrong Cork Company, Industrial Adhesives Department, 8005 Inland Road, Lancaster, Pennsylvania. In Canada, please write to 6963 Decarie Boulevard, Montreal.

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SCIENTIFIC AMERICAN

MAY, 1954 VOL. 190, NO. 5

The Electoral Switch of 1952

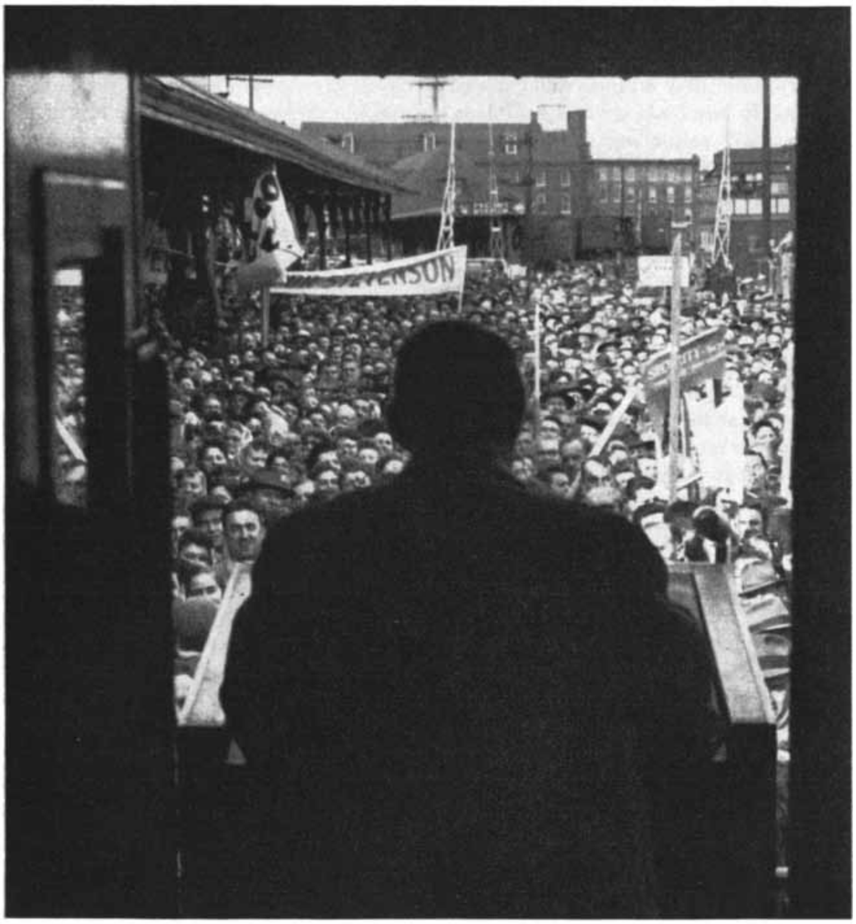
The last Presidential election represented a major change in the behavior of the U. S. electorate. An account of a large-scale study of what kinds of voters changed and why

by Angus Campbell, Gerald Gurin and Warren E. Miller

In November, 1952, the largest turnout of voters in U. S. history (61 million) toppled from power a Democratic administration which had won five consecutive Presidential elections. What were the motives behind this great swing of voters to the Republican candidate? With the support of a grant from the Carnegie Corporation, the University of Michigan Survey Research Center undertook a nationwide study to provide as full an answer as possible to that intriguing question. In the fall of 1952 we interviewed a national sample composed of 2,000 adults, chosen by methods of probability sampling to guarantee a proper representation of the entire electorate. We used detailed personal interviews of over an hour in length to probe their individual opinions, attitudes and perceptions. The analysis of this data now tells us a great deal about the 1952 election.

There are at least three ways in which one might approach the problem of trying to explain why voters vote as they do in a given election. First of all, one might focus on the effects of specific campaign events; in this case, for example, such events as Candidate Eisenhower's promise to go to Korea and President Truman's whistle-stop campaign in behalf of Candidate Stevenson. But such an approach does not go very deep, for two reasons: voters cannot be expected to be able to isolate the influence of single events from the total impact of the campaign, and the method disregards the basic attitudes which play so large a part in determining how an individual reacts to events. In any case, we feel confident that the 1952 result was not markedly affected by any dramatic occurrence during the campaign, for a majority of the voters had made up their minds on what candidate they would support before the campaign began, and the proportion for Eisenhower did not change much as the campaign went on. In other words, the effect of the campaign was to preserve the division of sentiment at just about what it was at the beginning. Of all the voters in the sample, 31 per cent said they had decided before the conventions how they would vote and 56 per cent of these voted for Eisenhower; 65 per cent had decided by the time the conventions were over and 60 per cent of these voted for Eisenhower; 85 per cent had decided when the campaign was well along and 58 per cent of these voted for Eisenhower; 94 per cent had decided by the last two weeks of the campaign and 58 per cent of these voted for Eisenhower (the remaining 6 per cent said they decided on Election Day or couldn't tell us when they made up their minds).

A second approach is to "explain" voting in terms of the voters' social and economic characteristics. It is well known that ever since 1932 the two major parties have drawn their main strength from different groups in U. S. society. During the Roosevelt era there emerged a "bloc" made up of certain economic, religious and regional groups which contributed a major proportion of the Democratic vote. This bloc came to be thought of as dependably committed to the Democratic cause, and the belief became widespread that the prospects of Democratic victory in any particular election depended mainly on how large a proportion of this bloc could be induced to go to the polls. But the 1952 election upset that assumption and exposed the limitations of any analysis of voting based solely on the sociological characteristics of the voters. The full dimensions of the upset are brought out by a comparison of our 1952 analysis with a similar study in 1948. The farmers, who were strongly Democratic in 1948, were as strongly Republican in 1952. Catholics moved from a heavy Democratic majority to an even split between the two parties. Young voters, who had been predominantly Democratic, now leaned to the Republican candidate. Contrary to the belief of some political observers, Eisenhower was not swept into office by a great shift among women voters, new voters or any other single group of the population. The impressive fact about the increase in the Republican vote in 1952 is that it came from virtually every subdivision of U. S. society except



PRESIDENTIAL CANDIDATES address the voters. At the top Candidate Eisenhower speaks in Nebraska City, Neb. At the bottom Candidate Stevenson speaks in Allentown, Pa.

those divisions in which the Republicans already held an overwhelming majority [*see table on page 34*].

These data tell us where the Eisenhower vote came from but they do not tell us why—what motives lay behind the voters' swing. To account for it, we must try a third approach: an analysis of the psychological forces. Human motivation of course is complex and often poorly understood by the individual himself. It may be studied at different levels and by different methods, ranging from deep interpretations of Rorschach inkblots to questionnaires and interviews. In our analysis we concentrated on three major motivational factors: the voter's identification with a party, his position on the issues between the parties and his response to the personal appeal or qualities of the candidates. We call these factors *party identification*, *issue orientation*, and *candidate orientation*. We constructed measures of these motivational forces. On the basis of the hour-long interview, using questions which were mainly of the free-answer type rather than the categorical yes-no variety, it was possible to score the extent of each voter's concern with the parties, issues and candidates respectively and, of course, the partisanship of this concern (Democratic, Republican or non-partisan). It was our assumption that these three measures would reflect three qualitatively different components of the total motivating force, and that taken together they would largely account for the extent of the respondents' participation in the election and for their choice of candidate. Both of these important assumptions were satisfactorily borne out by the results.

In considering these results let us first break down the supporters of each candidate into three groups: (1) party regulars who had voted for the same party in 1948, (2) voters who switched between 1948 and 1952 and (3) new voters. We find that of the total vote for Eisenhower 56 per cent came from party regulars, 24 per cent from switching voters and 18 per cent from new voters; of the vote for Stevenson, 74 per cent came from party regulars, 3 per cent from switching voters and 21 per cent from new voters. (Two per cent of the voters for each candidate did not tell us how they had voted in 1948.)

It is apparent that the margin of the Eisenhower victory was supplied by switching voters who had supported Truman in 1948; in other words, but for the 1948 Democrats who left their party,

MULTI-STAGE RANDOM SAMPLING provided 2,000 voters in 60 areas for the Survey Research Center study. Most of the areas were whole counties. Around large cities, however, only parts of counties were sampled because the sampling unit was the city.

General Eisenhower would not have gone to the White House.

A motivational analysis of the several groups gives a revealing insight into the dynamics of the 1952 election. The two groups who made up nearly all of the Stevenson vote (1948 Democrats and new Democrats) tended heavily to identify themselves with the Democratic Party and to take a Democratic position on partisan issues. However, they did not take a strongly partisan position on the personal qualities of the candidates; in other words, Eisenhower had about as much personal appeal for them as Stevenson. These characteristics were true of the Democratic supporters both in the North and the South [*see tables on page 35*].

The Republican support gave a strikingly different picture. Where the two Democratic groups showed similar motivational patterns, the three Republican groups were quite dissimilar from one another. Where the Democratic groups were characterized by strong party and issue motivation, the Republican groups had only one strong motivation in common—admiration of the Republican candidate. Of the new voters who supported Eisenhower, only a minority identified themselves with the Republican Party, and a significant number considered themselves Democrats. Of the switchers, very few assumed the Republican Party label, especially in the South. Moreover, in the North a majority of the new voters and switchers for Eisenhower did not take a position favoring the Republican Party's stand on issues, although it is of interest that the issue position taken by the defecting Democrats was significantly different from that held by the two Democratic groups who stayed with their party. In the South both the switchers and the new Republicans did incline to the Republican issue position.

The generally favorable reaction to Eisenhower's personality of all the groups that voted for him is unmistakable. A sizable number in each group, to be sure, appeared "non-partisan" on the candidates' personal qualities (especially in the South), yet among strikingly large percentages of them the General held high favor over Governor Stevenson. This strong leaning to Eisenhower as a person appears to have been the one factor which united all the groups that voted for him.

We find in summarizing these tables that the "regulars" of both parties were most consistently partisan in all of the measures we dealt with. The new Democrats also seemed firmly committed to their party, and to its issues. In contrast, the new voters who preferred Eisenhower were rather ambiguous in their positions on parties and issues. The Democrats who switched to Eisenhower tended to identify themselves still with the Democratic party but to have an ambivalent position on issues, at least in the North. In that region the new and switching voters for Eisenhower favored the Democratic side of the issues nearly as often as the Republican. Without venturing to predict how the various groups of voters will behave in future elections, one may suppose that the groups with the least consistent patterns will prove least stable in the event of changing political circumstances. Whether these changes will increase Republican or Democratic partisanship remains to be seen.

Our data were not as satisfactory in accounting for turnout as for choice of candidate. As expected, partisan people voted in greater numbers than those who were scored "non-partisan" on parties, issues and candidates. There was clear evidence, however, of the influence of variables other than those we considered,

CHANGE IN REPUBLICAN VOTE

	1948	1952
SEX		
MEN	44	57
WOMEN	47	59
AGE		
UNDER 35	37	54
35 to 44	39	54
45 to 54	53	58
55 AND OVER	54	64
RELIGION		
PROTESTANT	53	64
CATHOLIC	34	49
EDUCATION		
GRADE SCHOOL	32	51
HIGH SCHOOL	46	57
COLLEGE	76	74
OCCUPATION		
PROFESSIONAL AND MANAGERIAL	80	70
OTHER WHITE COLLAR	50	65
SKILLED AND SEMI-SKILLED	22	45
UNSKILLED	26	33
FARM OPERATORS	35	64
TRADE UNION AFFILIATION		
MEMBER	19	43
NON-MEMBER	56	64
ANNUAL INCOME		
UNDER $2,000	36	58
$2,000 TO $2,999	31	54
$3,000 TO $3,999	51	53
$4,000 TO $4,999	52	50
$5,000 AND OVER	68	68

VOTERS IN EACH GROUP at the left who chose the Republican candidate in 1948 are compared by per cent with those in the group who chose the Republican candidate in 1952.

for some apparently highly motivated people did not go to the polls, while some who by our measures seemed weakly motivated did vote.

Our three-factor theory of the motivation of the vote can nonetheless be applied to explain the unusually large turnout in the 1952 election. We do not have fully comparable data from the 1948 election, but some gross comparisons are possible. The strength of party identification probably did not change much between 1948 and 1952, nor does there seem to have been much difference in the sharpness of division over domestic issues. However, foreign affairs, which had been relatively unimportant in the 1948 campaign, took on a strong party significance in 1952. The personal impact of the candidates also was stronger in 1952. The presence of General Eisenhower as a candidate provided a personal element in the campaign which was largely missing in the previous contest between Truman and Dewey.

This increase in the importance of the issue and candidate factors in the 1952 election was associated not only with the increased turnout but also with the Republican victory. The major domestic issues that came to prominence in the 1952 campaign—particularly governmental corruption and high taxes—worked to the disadvantage of the Democrats. The highly charged foreign situation—the cold war generally and Korea specifically—also was very unfavorable to the Democratic cause. The personal popularity of Eisenhower was of course highly advantageous to the Republicans. While most voters did not respond unfavorably to Stevenson, his personality had far less impact on the electorate than Eisenhower's.

It is of interest that those of our respondents who voted for Eisenhower were much more likely to speak favorably of the Republican Party because of its presumed ability to handle pressing domestic issues than in relation to what it might do about foreign affairs. On the other hand, they were much more prone to think that Eisenhower provided an answer to the foreign situation, particularly the Korean War, than that he had a solution to domestic problems. A great many voters found a reassuring association between the General and their concern over the international crisis.

Without presuming to assign absolute values to the strength of the three factors we have studied, we have been able to show the similarities and contrasts of the motivational patterns which characterized the major components of the 1952 vote. The same type of analysis can be applied to other groups within the electorate; for example, to demographic groups such as farmers or young people, who, as we have seen, made significant shifts in voting behavior between 1948 and 1952. It would be highly desirable to apply this three-factor type of analysis to a series of election situations. The study of changes which occur from election to election would enhance our understanding of the forces that move the voter.

The three-factor theory of motivation we used in this analysis may be applied to other problems of perhaps more basic importance. What other kinds of behavior, political or otherwise, lend themselves to explanation in terms of group loyalties, ideological commitments and reactions to personalities? In what kinds of situations do people tend to react to one rather than another of these motivational themes? What happens when these factors are in conflict rather than mutually supportive? These are questions for future research.

STEVENSON VOTERS

POSITION TAKEN	IN NORTH		IN SOUTH	
	1948 DEMOCRATS	NEW VOTERS	1948 DEMOCRATS	NEW VOTERS
ON PARTY				
CONSIDERED THEMSELVES DEMOCRATS	78	74	90	89
NONPARTISAN	19	26	6	11
CONSIDERED THEMSELVES REPUBLICANS	3	0	2	0
NONCOMMITTAL	0	0	2	0
ON ISSUES				
FAVORED DEMOCRATIC STAND	58	49	52	41
NONPARTISAN	23	32	26	31
FAVORED REPUBLICAN STAND	14	16	20	23
UNDECIDED OR NONCOMMITTAL	5	3	2	5
ON CANDIDATES				
LIKED STEVENSON	33	23	12	16
NONPARTISAN	49	49	70	61
LIKED EISENHOWER	18	28	18	23

MOTIVATIONS OF STEVENSON VOTERS are suggested by this breakdown in per cent. These voters were divided into two groups: Truman voters in 1948 and new Democrats. These groups tended to favor the Democratic Party but were split on personalities.

EISENHOWER VOTERS

POSITION TAKEN	IN NORTH			IN SOUTH		
	1948 REPUBLICANS	NEW VOTERS	SWITCH VOTERS	1948 REPUBLICANS	NEW VOTERS	SWITCH VOTERS
ON PARTY						
CONSIDERED THEMSELVES REPUBLICANS	73	43	16	61	38	9
NONPARTISAN	22	32	36	28	14	14
CONSIDERED THEMSELVES DEMOCRATS	4	22	48	11	48	77
NONCOMMITTAL	1	3	0	0	0	0
ON ISSUES						
FAVORED REPUBLICAN STAND	61	36	35	57	55	37
NONPARTISAN	23	24	30	18	31	40
FAVORED DEMOCRATIC STAND	10	30	33	25	10	14
NONCOMMITTAL	6	10	2	0	4	9
ON CANDIDATES						
LIKED EISENHOWER	65	56	58	57	42	47
NONPARTISAN	26	40	35	43	55	42
LIKED STEVENSON	9	4	7	0	3	11

MOTIVATIONS OF EISENHOWER VOTERS are suggested by this breakdown. These voters were divided into three groups: Dewey voters in 1948, new Republicans and 1948 Truman voters who switched their vote. All these groups admired Eisenhower.

TIDES IN THE ATMOSPHERE

Like tides in the sea, they rise and fall twice a day. Unlike sea tides, they are due to the sun more than the moon. Still the moon contributes a tiny beat to their regular oscillation

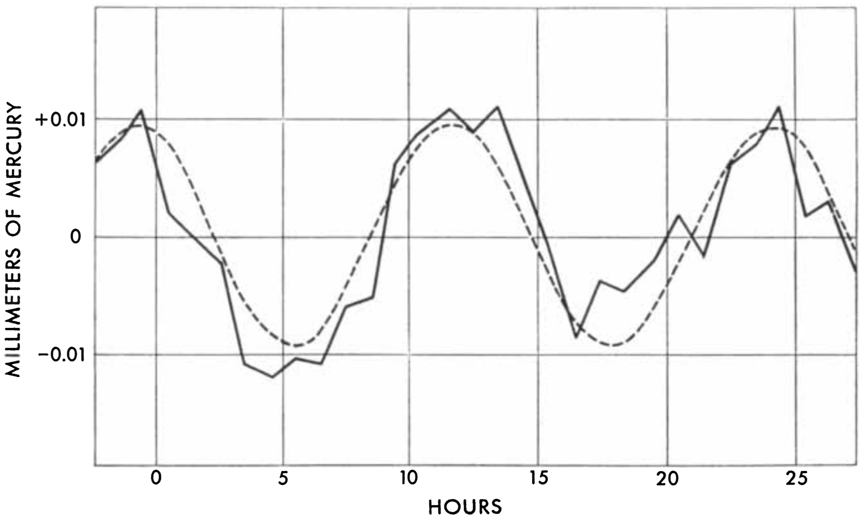
by Sydney Chapman

Twice each day the oceans of the earth rhythmically rise and fall under the pull of the moon. Everyone knows of the sea tides. But very few people realize that the moon also creates tides in the atmosphere. Far over our heads daily moon tides heave and billow on the bosom of our ocean of air. This gentle "breathing" of the atmosphere is so much less apparent than the ocean tides and so masked by the much more powerful effects of the sun on the atmosphere, that to detect it at all is a labor of infinite pains—like, say, searching for tritium in rainfall. Yet it has interested some great scientists, beginning with Isaac Newton. Much of the lure in studying it is simply the challenge of a difficult job. But besides that, the atmospheric moon tide is almost a laboratory case of a single simple experiment, performed by the moon upon the air, and from it we may learn something about the atmosphere in which we live.

Roger Bacon, the brilliant 13th-century scientist, was one of the first to study the relation of the ocean tides to the moon. Each day a high tide occurs when the moon is overhead, and in any given place it arrives nearly an hour later every successive day, as the moon does. One could logically conjecture that the waters were pulled up by the attraction of the moon. But what of the other daily high tide, which comes when the moon is on the opposite side of the earth? Bacon failed to guess the answer, but Newton later succeeded in explaining it: the high tide on the opposite side is due to the fact that there the moon pulls the earth away from the waters. Thus there are two simultaneous tidal bulges on the earth's opposite sides, and as the moon moves across the sky the two bulges follow it, forming a double wave traveling westward around the globe.

The horizontal ebb and flow of the tides of course arises from the fact that the water not directly beneath the moon is pulled obliquely, and the horizontal component of the moon's force makes it move laterally.

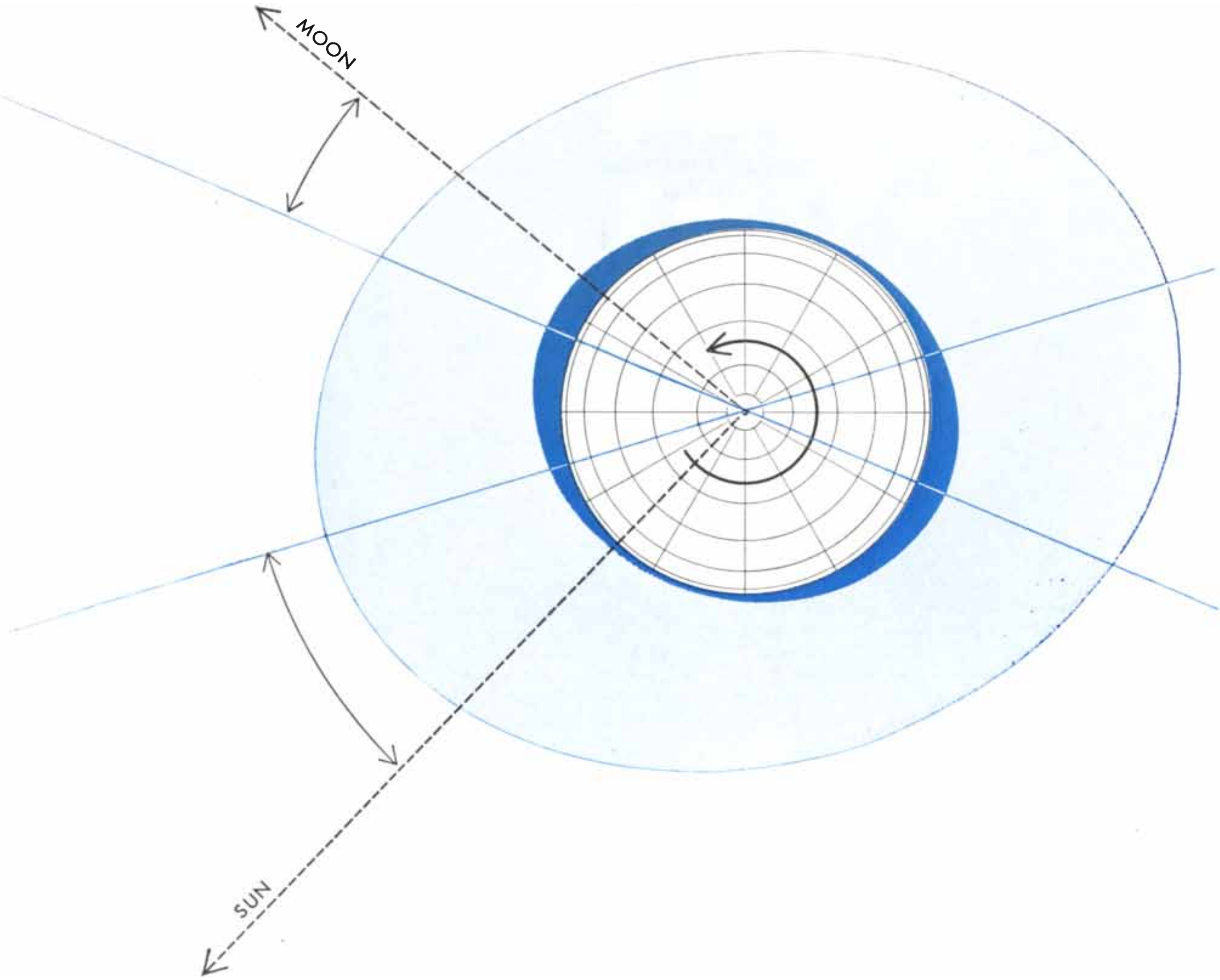
The moon's tidal forces act on the solid as well as on the fluid parts of the earth. Although the solid matter cannot flow like the waters of the oceans, its elastic substance does bulge slightly toward and away from the moon. The twice-daily rise and fall of the earth under our feet is quite imperceptible to our senses, but delicate instruments have detected it. The observations indicate that the earth as a whole is about as elastic as steel.



LUNAR TIDE in the atmosphere is a tiny effect measured in hundredths of a millimeter of barometric pressure. The solid line was plotted on the basis of hourly observations at Greenwich, England, for 6,457 days. The broken line averages the effect. The pressure rises and falls twice in 25 hours. Like the moon, high tides arrive an hour later each day.

It was Newton, apparently, who first suggested that there must be tides in the atmosphere. He added that they would be so small as to be imperceptible. Nevertheless, like the earth tides, they have been detected by careful measurements and analysis.

The tidal rise and fall of the seas is visible and easily measured because the sea has a definite level with respect to the land. Tide gauges record the changing level of its surface. In mid-ocean the tides cannot be measured in this way. There the only method of gauging the rise and fall of the surface is by changes in the weight or pressure of the water, as measured by a pressure gauge on the sea bottom. Essentially the same device must be used to record the tides in the atmosphere, not only because there is no yardstick to measure the atmosphere's height but because it thins away gradually and has no well-defined upper surface. The tide gauge for the atmosphere is a barometer, which measures the



SEA AND AIR TIDES are shown on a vastly exaggerated scale by this schematic diagram of the earth seen from above one pole. The long axis of the sea tide (*dark blue*) lags about five degrees (*curved arrow at top*) behind the moon because of the pull of the sun. The long axis of the air tide (*light blue*) precedes the sun by about a fifth of the angle (*curved arrow at bottom*) between sun and moon.

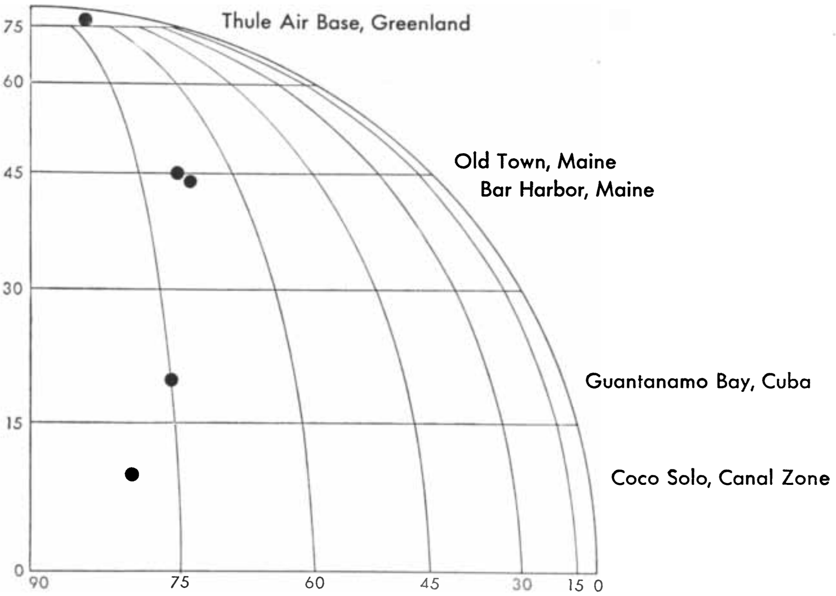
weight, and thereby the height, of the overlying air. High and low tide in the atmosphere correspond to higher or lower barometric pressure.

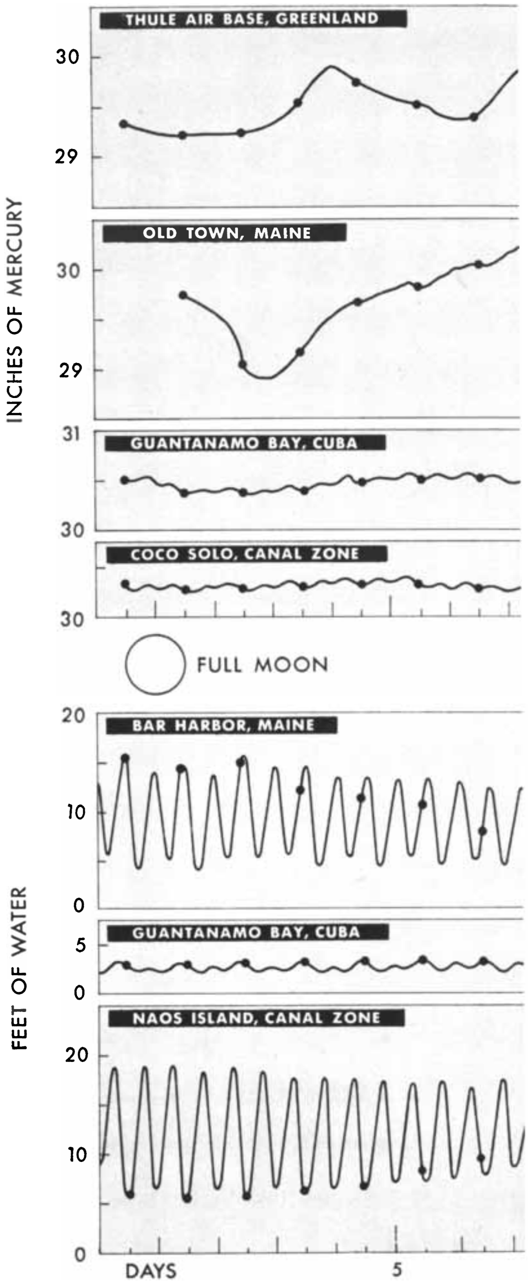
A century and a quarter ago the great French mathematician and astronomer Pierre Laplace made the first systematic attempt to detect the moon tides in the atmosphere by means of barometric records. He had developed a theory of tides in an ideal ocean, and from an adaptation of this theory to the atmospheric ocean he calculated that the lunar tides should produce a daily rise and fall of one quarter of a millimeter of mercury in the tropics and less in other latitudes. Laplace analyzed a series of 4,752 daily barometric readings taken over an eight-year period at the Paris Observatory. He failed to find any significant lunar pattern and decided that at least 40,000 barometric readings would be needed. Other observers who followed up his work likewise failed, though one had 30,000 readings to analyze.

The complications that make it difficult to detect the tiny lunar effect are two: irregular air fluctuations and the tidal forces and daily thermal action of the sun. To see how they confuse the picture, let us look at some records of sea tides and barometric readings which have been supplied to me by the courtesy of Harry Wexler of the U. S. Weather Bureau. All were taken during the month of January, 1953. The tide records come from three locations: Naos Island, Canal Zone; Guantánamo Bay, Cuba; Bar Harbor, Maine. The barometer records are from Coco Solo, Canal Zone; Guantánamo Bay, Cuba; Old Town, Maine; Thule, Greenland.

All seven of these stations are near the same meridian. Two of the stations providing the air-pressure records are tropical (Canal Zone and Cuba), one is mid-latitude, and the fourth is polar. The readings at the several stations are shown on the next two pages. On each of these curves the noon points are marked by dots.

The three sea tide records all show the twice-daily rise and fall of the water. High and low tides come later each day, like the moon. They vary moderately in range, with two maxima about two weeks apart. But when we look at the barometric curves we see important differences. The barometric readings at the two tropical stations show a twice-daily rise and fall but do not follow the changing moon schedule: the highest air pressure comes each day about 10 a.m. and 10 p.m. This means that the sun, not the moon, causes the pressure changes. As for the stations in Maine and Greenland, their barometric patterns show hardly any rhythm at all. The wide barometric





BAROMETRIC AND TIDE RECORDS from six stations are compared for the month of January, 1953. The four records at the top of the group at the right show barometric variations. The three records at the bottom show sea tide variations. The related phases of the moon are indicated between the two sets of records. The dots on each curve represent its position at noon. All the stations, indicated by the dots on the terrestrial coordinates above, are near the same meridian. Naos Island, which is not shown, is at the same latitude as Coco Solo. The curves in the illustration were plotted by Dan Wilder of the University of Alaska.

variations there are associated with the continual weather changes typical of temperate and high latitudes. In the tropics, where the weather is more stable, the barometer keeps nearly the same level from day to day and from month to month, except during the occasional hurricanes or typhoons.

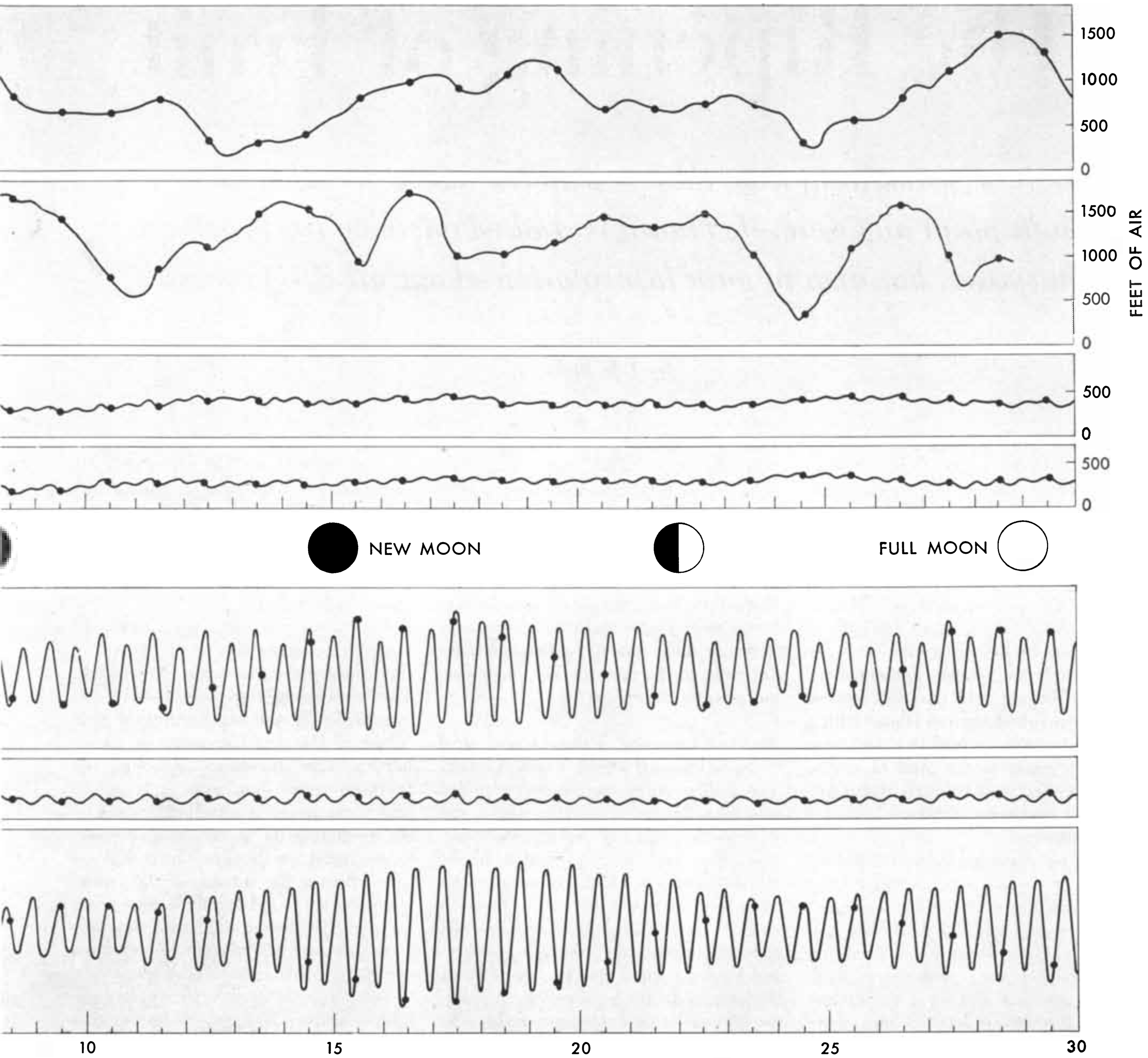
What these records make clear is that the moon tides in the atmosphere are obscured by two factors due to the sun: the sun's tidal force and daily heating of the atmosphere and the vagaries of the air (most pronounced outside the tropics). The sun exerts a tidal pull like that of the moon; this accounts for the semimonthly high "spring" tides in the oceans, when the sun's pull reinforces the moon's, and the "neap" tides, when the sun partly counteracts the moon. In spite of the sun's immensely greater mass, its tidal force on the sea is less than that of the moon. Tides are due to the difference between the pull at the center of the earth and the pull at other points. Thus while the sun's total attraction is greater, the difference at different points of the earth is smaller, because of its greater distance from us. The moon's tidal power in the sea is 2.4 times that of the sun.

However, in the atmosphere the sun-tide drowns out the moon tide. One reason is that the atmosphere has a natural period of vibration which nearly coincides with the sun's period of 12 hours; the resonance amplifies the vibration. Certain air waves created by the sun's heat also have a 12-hour period and are similarly amplified. These and other factors, still unknown, make the sun tide 15 to 20 times as strong as the moon tide in the atmosphere.

To use a musical analogy, the moon tide and the sun tide correspond to two pure notes of different "pitch" and intensity. The moon tide note has one vibration in 12 hours and 25 minutes; the sun tide note has a slightly higher "pitch"—one vibration in 12 hours. In a barograph recording of the music of the atmosphere in middle latitudes, the irregular surf of the winds is a deep, booming roar, the sun tide is a barely audible monotone and the moon tide is a muted note which can be heard only by a specially attuned ear.

The moon tide note can be isolated by a method which amounts to listening for the lunar frequency in the barometric pressure records. Its frequency is one vibration in half a lunar day—12 hours and 25 minutes. The barograph curve for a long period is chopped into equal sections, each of the length of the lunar half-day. The average height of the curve at each moment of the lunar half-day is then obtained by adding up the curve heights at specific points and dividing by the number of half-day periods. The mean curve thus computed shows the rise and fall of the moon tide. The sun tide's rise and fall, having a different period, will cancel itself out if the record covers at least 1,000 successive lunar half-days. It takes longer to isolate the moon tide note from the large irregular variations, but since they are random they eventually average out. Theory shows that they should be smoothed out in 10,000 lunar half-day periods.

This was the method by which Laplace tried to find the moon tide, but he failed because he did not have enough observations to eliminate the irregular variations at the latitude of Paris. The moon tide was first detected in 1842



from mercury readings at a station in the tropics. John Henry Lefroy, director of a British station on the island of St. Helena, found over a 17-month period a regular lunar rise and fall of about a tenth of a millimeter on the barometer. In 1918, by analyzing the records of 64 years at the Greenwich Observatory in England, I succeeded in finding the moon tide for the first time outside the tropics. The rise and fall amounted to less than a hundredth of a millimeter of mercury—equivalent to about seven and three quarters inches of air!

The height of the lunar air tide has now been determined at more than 60 places around the globe. It varies far less than the ocean tides, owing to the absence of "shores" in the atmosphere. The great Rocky Mountain chain seems to have a definite, though small, effect upon it. The most surprising feature of the moon tide is that the daily high tides come an hour or two later in January and February than in May and June.

In recent years we have found that the moon tide can be read on a natural tide gauge in the atmosphere. It is the ionosphere, the great layer of electrically conducting particles far above the earth. By bouncing radio signals from the ionosphere we can measure its height, and in this manner it has proved possible to follow the double wave of the moon tide around the earth. In the ionosphere the rise and fall of the moon wave is as much as a mile or more!

Many other interesting facts have been discovered about the still, small voice of the moon in the music of the atmosphere, including the fact that the tide produces a waxing and waning of the cosmic-ray meson showers falling upon the earth. So the cultivated scientific curiosity that led Laplace and his followers to look into this tiny phenomenon has yielded surprising enlightenment. It seems certain that the study of the atmospheric moon tide at all available levels will help toward a better understanding of the complex aerial mantle of the earth.

The Ripening of Fruit

It is a transformation that resembles aging in other tissues, both plant and animal. Thus it is studied not only for practical purposes, but also to gain information about all life processes

by J. B. Biale

Fruits have inspired literature and history ever since the first lady of the race reached out for the apple of the tree of knowledge. The wisdom of the sages of India was nourished by the banana, known as *Musa sapientum*—the fruit of the wise man. It is common folklore that an apple inspired a 17th-century physicist to formulate the laws of gravitation. In the pre-gunpowder age fruits served as a fairly consequential weapon. We are told that the ancient Hebrews revolted against Herod with a barrage of citrons—a fruit like the lemon but many times larger. And of course fruits have fed man through all his history, since long before he knew language or agriculture.

Today biologists are interested in fruit not only as a food but as a fascinating material for the study of life processes. The career of a fruit, from its early embryonic stage to senescence, from the cradle to the grave, spans only a short time. In the brief months of its lifetime it goes through essentially the same chemical and physiological transformations as other living things, and its development can be followed under controlled laboratory conditions.

What is a fruit and how is it formed? A layman and a botanist may have divergent ideas on this question. We all agree that the apple, pear, plum, orange, banana and the more exotic mango and cherimoya are fruits. But how about the avocado, tomato, cucumber, squash, eggplant? A layman would call these vegetables, but a botanist has no hesitation about identifying them as fruits. Any time you bite into the expanded ovary wall of a plant's flower, you eat a fruit. Botanically a fruit is composed of structures responsible for the reproductive function of the plant. The general form of these structures is shown in the diagram of a typical flower at the top of the opposite page. The parts that play the main roles in fruit formation are the stamen—the male organ that bears the pollen or sperms of the plant—and the ovary, which has one or more ovules—the potential seeds. The ovule, a tiny egg-shaped structure attached by a placenta to the ovary wall, contains an embryo sac in which at the time of fertilization there are eight nuclei [*see middle illustration on opposite page*].

In most cases one of these nuclei must be fertilized if a fruit is to be formed. The pollen grains germinate; a pollen tube grows down through the stigma and style in the pistil and through the ovary wall; the tube delivers pollen nuclei within the sac; one of these sperm nuclei fuses with an ovule nucleus to form an embryo, or seed; and the ovary wall then expands, forming the fruit. But as everyone knows, some fruits develop without forming seeds; for instance, the banana, the pineapple, the seedless orange. In some cases there is pollination but no fertilization. The pollen tube stops growing before it has penetrated into the ovule. How can mere pollination stimulate the ovary to grow? The first clue came when it was discovered that dead pollen or extracts from pollen could cause a plant to set fruit. A search for the active substance narrowed it down to an extract which had properties like those of auxins, or plant hormones. By using synthetic auxins investigators succeeded in producing seedless tomatoes and a number of other fruits.

So the present idea is that auxin is required for the growth of the ovary into a fruit. One auxin commonly found in plant tissues is the growth hormone indole acetic acid. Experiments have shown that this hormone can induce the formation of seedless fruit. Further, it has been demonstrated that indole acetic acid can be made by the oxidation of tryptophane, an amino acid known to be present in pollen. It seems likely that pollen contains an enzyme which causes the conversion of tryptophane or other substances into auxin.

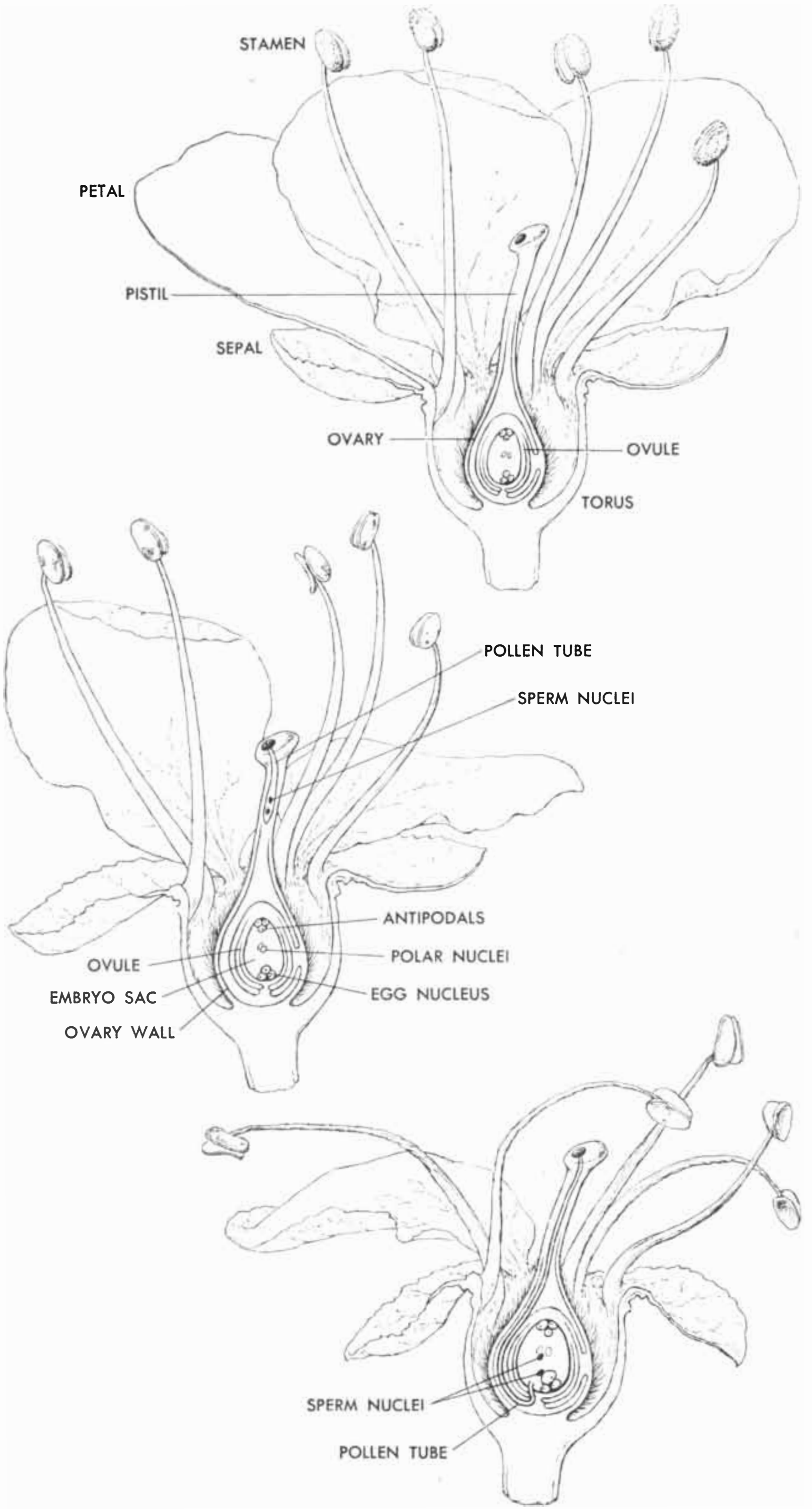
In the case of fruits with seeds we know that a major role in the growth of the fruit is played by auxin in the seeds. This was brought to light clearly and beautifully by the experiments of Jean Nitsch of Harvard University on strawberries. The strawberry develops not from an ovary but from a tissue to which the ovary is attached, known as the receptacle. Its "seeds" (more correctly, its fruits) are those tiny tufts that appear all over the surface of the strawberry. Nitsch found that if all these seeds are removed during the fruit's development, the growth of the strawberry stops completely. When he left a narrow ring of seeds around the strawberry, it grew into a flattened shape. Then he discovered that if a denuded strawberry is covered with naphthoxyacetic or indole butyric acid in a lanolin paste, the fruit develops normally. Chemical analysis has shown that the seeds are rich in the auxin required for growth. Each seed feeds auxin to a limited region.

In fruits with larger seeds a single seed may supply sufficient auxin for the whole fruit. Recently it has been found that an even richer source of auxin is the endosperm, the tissue in which the seed is embedded. Apparently the seed and the fruit compete for the auxin produced by the endosperm; while the seed is growing rapidly, the growth of the fruit is rather slow. Fruit can be forced to a bigger size if synthetic auxins are applied during this period.

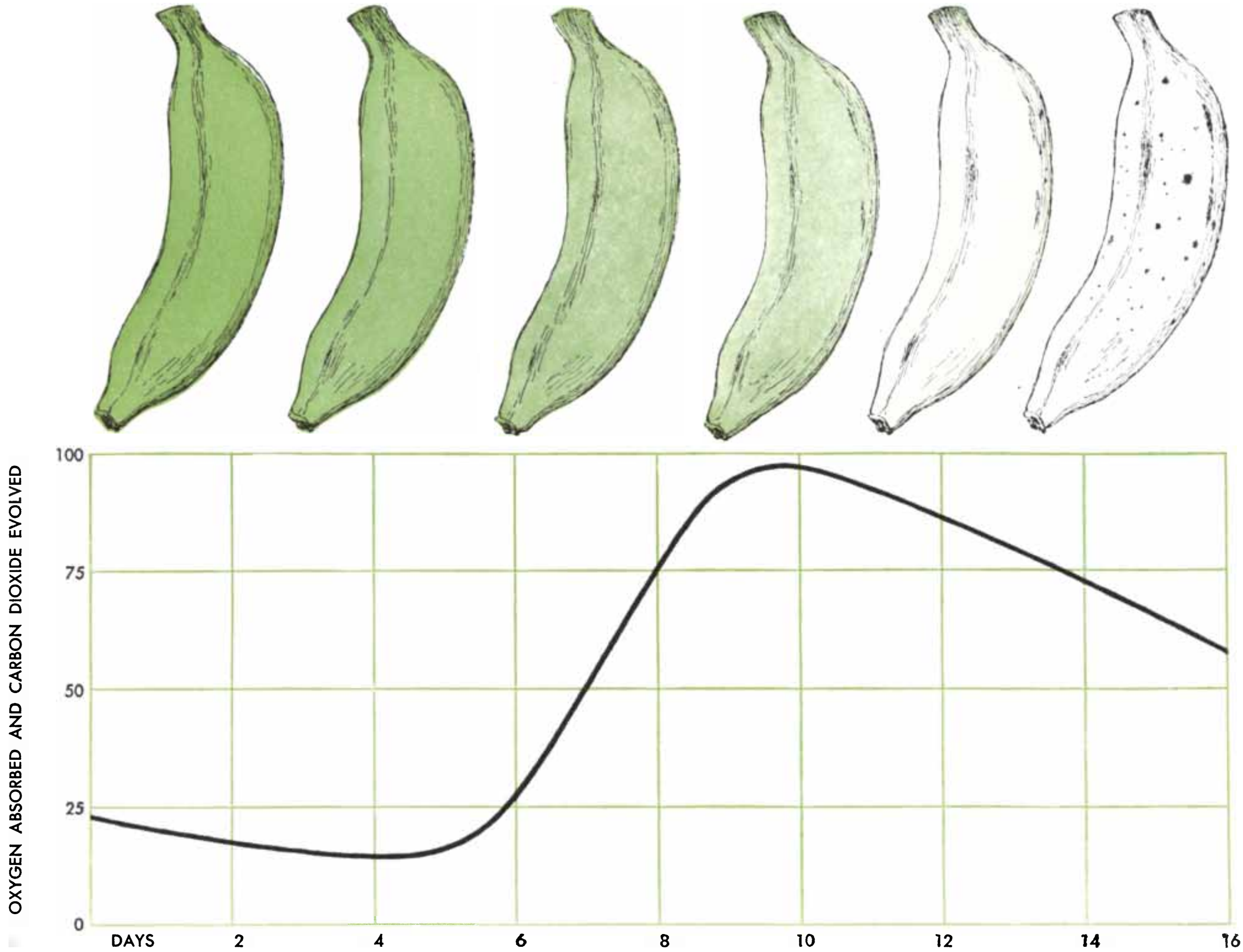
Every fruit has four stages of development. In the first stage, immediately after fertilization, it grows by division of cells. The apple, for example, forms 500,000 to one million cells by successive divisions in the first three or four weeks. Then the cells stop dividing and begin to grow by expansion. During this second stage, lasting up to two or three months, the cytoplasm of each cell moves out toward the edge and the interior is occupied by sap-filled vacuoles, which may take up 80 per cent of the cell volume. Sugars accumulate in the vacuoles; the cytoplasm, which up to now has consisted chiefly of proteins, adds starch. When the fruit has reached its full growth, there follows a third stage in which substances responsible for its aroma and flavor are formed. At the end of this stage, which lasts about as long as the second stage, the fruit is ripe, or at least ready to be picked for ripening. In the fourth stage—senescence—the fruit undergoes conspicuous chemical changes.

Most fruits will eventually ripen to the edible stage on the tree, but some (*e.g.*, the pear and the banana) are best picked green and allowed to ripen under controlled conditions, while a few (*e.g.*, the avocado) will never ripen if left on the tree. The avocado will hang on the tree for months without dropping or reaching the soft, edible state (except when its stem is injured), but if picked when mature it will ripen in one or two weeks at room temperature. The contrasting behavior of the avocado on and off the tree is an intriguing problem. One theory is that as long as it is attached to the tree the fruit is continuously supplied with a substance that inhibits ripening.

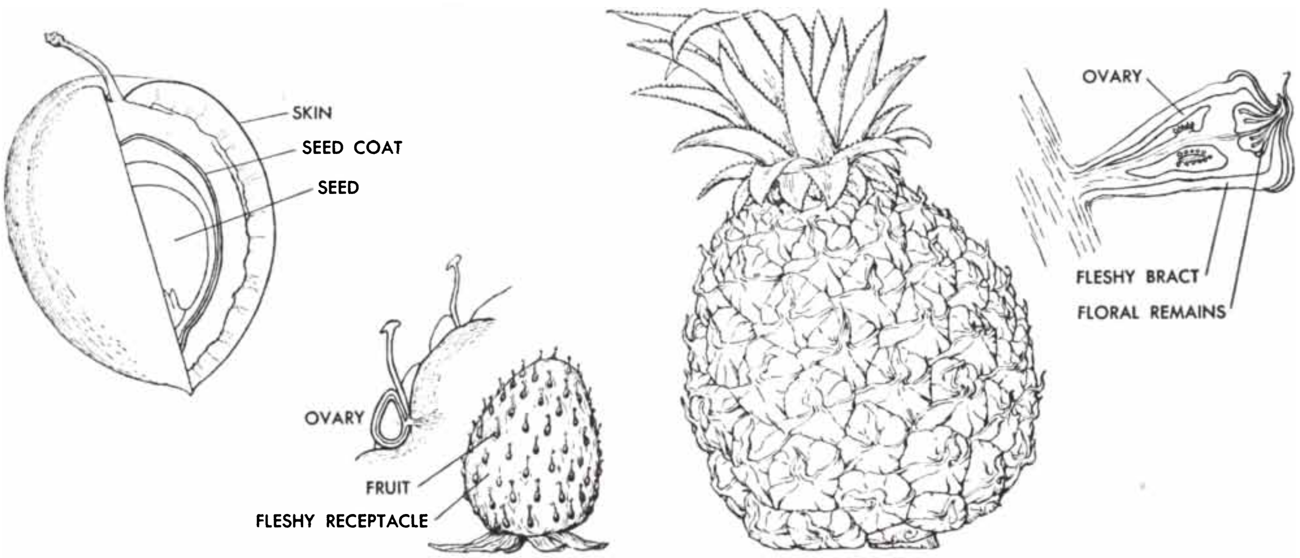
The ripening process of fruits has been studied intensively under well-controlled conditions in the laboratory. We have learned a great deal from these studies. Part of what we have learned has to do with the chemical composition of fruits, which is important from the point of view of nutrition as well as the ripening process. The table on page 44 shows the principal chemical components of a number of fruits. In our society, with its wide range of available foods, the fruits are important mostly as a source of vitamins. Nearly all of them are high in vitamin C; the citrus fruits, the strawberry, mango, papaya, black currant and guava especially so. Fruits are not the best source for the B vitamins, but these vitamins are crucial to the fruit. In combination with specific proteins the B vitamins make up respiratory enzymes. And respiration plays the dominant role in the development of fruit. For fruits, as for



REPRODUCTION OF FRUIT is illustrated by these partially diagrammatic drawings of the apricot flower. The top drawing shows the fresh blossom. One pollen grain from an open stamen has fallen on the pistil. In the middle drawing the pollen tube, bearing the sperm nuclei, has begun to grow. Fertilization takes place when the pollen tube enters the ovule and a sperm nucleus unites with an egg nucleus to produce a new seed, or fruit. In the bottom drawing this begins to grow. By then some petals have fallen and the stamens withered.



RIPENING BANANA undergoes a progressive change of color from deep green to full yellow after ripening is begun. The respiration curve shows that oxygen absorption equals carbon dioxide evolution. The fruit is ripe just after the high point or "climacteric."



TYPES OF FRUIT are represented by the plum, strawberry and pineapple. The first is a simple fruit, so described because it has one seed. The second is an aggregate fruit with many seeds or fruits in one tissue. The third is a multiple fruit from many flowers.

leaves, roots, bacteria, animals and every living thing, respiration is the very cornerstone of life.

In general terms respiration involves the reaction of one molecule of sugar with six molecules of oxygen to yield six molecules of carbon dioxide, six molecules of water and 680 kilocalories of energy. We find that the respiration of fruit, measured by the cells' uptake of oxygen, is high during the stage of cell division and gradually decreases during enlargement and maturation of the cells. After the cells mature, there comes a sharp rise in respiration rate, followed by a decline. This phase of respiration has been named the "climacteric." Before the climacteric the fruit apparently is resistant to disease. After it, senescence begins to set in, and the fruit becomes susceptible to physiological diseases and invasions by fungi. It is during or immediately after the climacteric that fruits ripen: apples, pears and bananas turn from green to yellow, some avocados from green to dark brown.

Of the chemical changes associated with ripening, perhaps the most characteristic involves the pectins—gel-forming substances. Pectins consist of long chains of galacturonic acid with methyl groups $(-CH_3)$ attached to the carboxyls $(COOH)$. When all the methyl groups are split off, the remaining galacturonic acid chain is referred to as pectic acid. As fruit ripening sets in, a water-insoluble protopectin decreases sharply and the pectin content increases. After the fruit is fully ripe, the total amount of pectic substances declines. Meanwhile in some fruits (such as the banana) starch is converted to sugar; in others (*e.g.*, the persimmon) tannins disappear; in many the green pigment chlorophyll disappears. As the masking effect of chlorophyll is removed, other pigments become visible and the fruit assumes its characteristic "ripe" color. In some cases the color is deceiving. A green orange may have as high a sugar content as a golden one, for the changes in the rind of the fruit do not always reflect the condition of the flesh.

Temperature has a marked effect on the course of respiration during the climacteric stage. Within certain limits, the higher the temperature, the sharper the rise and the higher the peak. Low temperatures tend to suppress or completely obliterate the climacteric. If the fruit is kept for a prolonged period at rather low temperatures, the ripening process may be affected adversely. Some fruits are more sensitive than others to low-temperature injuries. Bananas, for example, should not be kept below 53 degrees Fahrenheit. For best results avocados should first be ripened at room temperature and afterwards placed in the refrigerator, rather than *vice versa*. Lemons should be stored at about 55 degrees and grapefruit at 50 degrees.

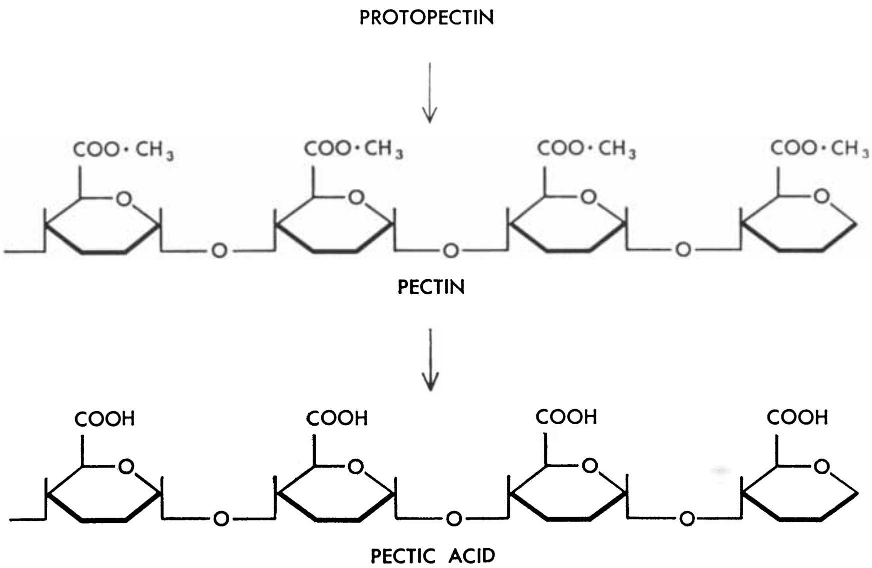
Fruit physiologists have attempted to slow down the ripening process by storing fruits in atmospheres with less than the usual amount of oxygen (21 per cent in dry air). A low oxygen level retards the onset of the climacteric, but if it is too low, it promotes fermentation and causes accumulation of toxic substances. For many fruits storage in an atmosphere with 5 to 10 per cent oxygen seems to be best: it delays the climacteric, cuts down respiration, prolongs storage life and improves the quality of the fruit.

In the early years of this century many fruit growers made a practice of ripening citrus fruits by forced "curing" in a room with a kerosene stove. They supposed it was the heat that turned the fruit from green to yellow, but investigations showed that incomplete combustion products of the kerosene were responsible. The most active gas was eventually identified as ethylene. As little as one part per million of ethylene in the air will speed the onset of the climacteric rise in respiration. In some fruits, such as citrus, it merely brings about an accelerated disappearance of chlorophyll from the peel. In the banana, on the other hand, it causes an earlier transformation of starch to sugar.

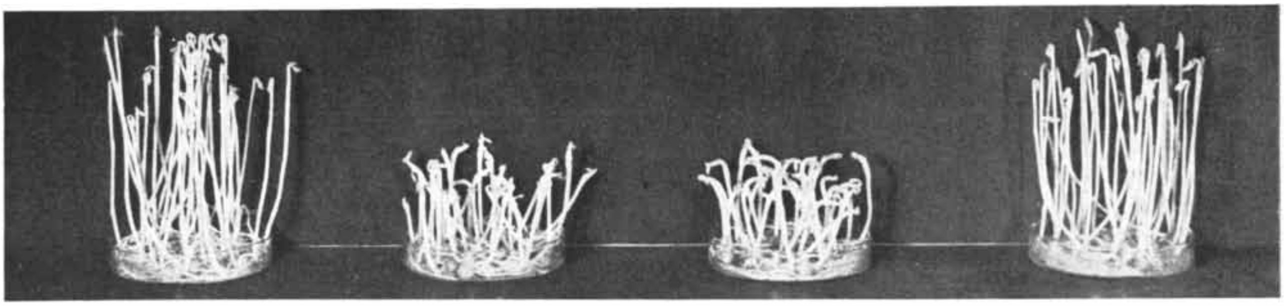
Since ethylene was observed to be effective in minute quantities, it became essential to find a sensitive method for detecting this gas. Pea seedlings were found to be highly sensitive indicators. By the use of this test it was discovered that a number of fruits not only were affected by ethylene but actually produced this gas during the climacteric stage. In a typical experiment air is passed at a constant rate through a jar of fruit and then into a container with pea seedlings kept in the dark. If ethylene is given off by the fruit, the seedlings grow thick, short and curly instead of tall and spindly [*see photograph on next page*]. This test has shown that the ethylene emanations occur only during the fruit's climacteric.

Whether ethylene is the cause or the effect of the rise in the respiration rate is difficult to tell from the pea test. With more precise chemical methods we have recently found evidence that in many fruits the production of ethylene definitely follows the rise in respiration. Moreover, the mango exhibits a typical climacteric but no detectable ethylene. We are inclined to favor the view that while ethylene affects the ripening process, it is not the master reaction. The search for the trigger mechanism that sets off the master reaction is now in progress.

This takes us into a new and fascinating field: the metabolic processes of particles in the cytoplasm of the cell. In order to study the chemical role of these particles in respiration, they must be separated from the other components of the cell. This is accomplished by a series



CHEMICAL CHANGE characteristic of ripening is the appearance of pectic acid. This derives from pectin, which consists of galacturonic-acid chains with methyl groups attached.



PEA-SEEDLING INDICATORS show the ethylene production of ripening avocados. At right are control seedlings grown without exposure to ethylene. Seedlings at left were grown in air from jar of avocados kept at 5 degrees C.; they show the fruit produced no ethylene. Next two sets of seedlings show effects of ethylene in air from avocados ripening at temperatures of 15 and 25 degrees C.

of centrifugations at different speeds. First the fruit cells are broken up in a Waring blender and centrifuged at low speed (500 times gravity). This removes from the fluid the cell nuclei, cell fragments and some whole cells. The remaining fluid is then subjected to a high-speed centrifugation (17,000 times gravity) which separates the tiny cytoplasmic particles, ranging in size from about half a micron to three microns.

These particles contain highly organized enzymes responsible for metabolic processes common to all living things. The enzymes break down pyruvic acid (a three-carbon compound derived from sugars) into carbon dioxide and water, and they also oxidize certain acids which play a vital role in the oxidation of pyruvic acid. Some of these acids have been found in fruits in fairly large quantities. In addition to their oxidative power, the particles in the cytoplasm of fruit cells are able to utilize the energy of oxidation to form key substances in the energy cycle of cells. They take up inorganic phosphate and add it to adenosine monophosphate (AMP) to form the diphosphate (ADP) and triphosphate (ATP)—a process known as oxidative phosphorylation. The phosphate acceptors or donors supply energy for the cell's chemical factory and for work performed by the organism.

The ability of cytoplasmic particles from avocados to carry on oxidative phosphorylation has been utilized to study the biochemistry of the ripening process during the climacteric rise. Particle suspensions were prepared from fruits at various stages in the climacteric cycle. Throughout the period of the ripening process the particles showed a high efficiency of phosphorylation: that is, a high ratio of phosphorus uptake per atom of oxygen used in respiration. But the addition of a small amount of dinitrophenol prior to the climacteric rise markedly reduces this efficiency. The oxygen uptake is not affected, but much less phosphorus is incorporated into the organic acceptors. Dinitrophenol is a substance which dissociates oxidation from phosphorylation; thus respiration can proceed at a fast rate without the formation of high-energy phosphate compounds. It was found, however, that during the climacteric cycle treatment with this reagent does not slow down phosphorylation. Evidently the relationship between these two major biochemical reactions—oxidation and phosphorylation—undergoes a change in the course of the climacteric.

We are inclined to conclude that fruit cells exhibit essentially the same laws that govern the growth, development and aging of every living thing—whether a plant, a microorganism or liver tissue.

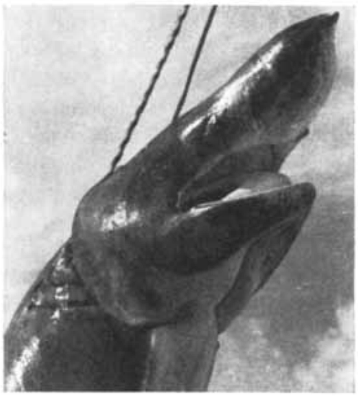
	WATER	PROTEIN	FAT	CARBO-HYDRATES	TOTAL ACID	MINERALS			VITAMINS		
						CALCIUM	IRON	PHOSPHORUS	C	B_1	B_2
TEMPERATE ZONE											
APPLE	84	.3	.4	12	.6	7	.4	12	6	.03	.01
APRICOT	85	1	.1	10.4	1.6	13	.6	24			
CHERRY	82	1.2	.5	10.5	.5	19	.4	30	9	.05	.02
GRAPE	82	.8	.4	14.9	.5	11	.3	10	4	.05	.03
PEACH	87	.5	.1	8.8	.6	10	.3	19	8	.05	.05
PEAR	83	.7	.4	8.9	.4	15	.3	18	4	.06	.07
PLUM	86	.7	.2	8.3	.9	20	.6	27	6	.13	.04
STRAWBERRY	90	.6	.6	5	1.3	34	.7	28	55	.03	.05
SUBTROPICAL											
AVOCADO	68	1.7	20	5		10	.6	38	16	.06	.13
DATE	20	2.2	.6	75		72	2.1	60	0	.09	.10
FIG	78	1.4	.4	20	.4	54	.6	32	2	.06	.05
GRAPEFRUIT	89	.5	.2	10	1.7	22	.2	18	40	.04	.02
LEMON	89	.9	.6	8	5.5	40	.6	22	50	.04	
ORANGE	87	.9	.2	11	1	33	.4	23	50	.08	.03
TROPICAL											
BANANA	75	1.2	.2	23	.4	8	.6	28	10	.04	.05
MANGO	81	.7	.2	17	.5	9	.2	13	41	.06	.06
PAPAYA	89	.6	.1	10	.2	20	.4	23	55	.03	.04
PINEAPPLE	85	.4	.2	14	1	16	.3	16	25	.08	.02

CONSTITUENTS OF FRUITS grown in temperate, subtropical and tropical climates are listed. The numbers in the first five columns refer to grams per 100 grams; those in remaining columns, to milligrams per 100 grams. Abundant elements are in bold type.

Kodak reports to laboratories on:

a deceptively simple isoprene polymer . . . a pleasant way to learn about lenses . . . setting the valves in a chemical plant

Fascinating hydrocarbon



This is a *basking* shark, so called because the non-pregnant female of the species loves to lie near the surface and bask, exposing the tip of her nose, her dorsal fin, and the top of her tail. A man who wrote a book about it claims he fired 300 machine gun rounds point-blank at one specimen and succeeded only in annoying the beast. Powerful enough to destroy a fisherman's net or boat with a casual flip of the tail, the basking shark is no more bloodthirsty than the herring, with which it shares a common diet of plankton.

We wish to advise that we have procured a quantity of basking shark liver oil and have molecularly distilled from it a colorless, high-boiling cut which is 90-95% *Squalene.*

About this deceptively simple isoprene polymer there appears to be plenty to investigate, aside from the riddle of why the basking shark and the cacao shark of East African waters accumulate so much of it. Its presence in olive oil and absence from vegetable oils likely to be palmed off as olive oil arouses the investigational instincts of law enforcement bodies. It is a precursor of cholesterol. Though it is a normal component of human sebum, in topical application it is reported to cause loss of hair without signs of inflammation. (Unfortunately, a consulting firm we hired to check this observation failed to confirm it.)

Squalene *is one of the products obtainable from Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).*

Lens movie

We have had a composer compose some original music for us. *Why?* To serve as background for a movie. *Are we in the business of producing movies with music in them to entertain people?* No, but the right kind of music in a movie helps hold people's interest while they learn. *Learn what?* Most anything. About photographic lenses, in this particular case. *What about photographic lenses?* About how they are designed and how the glass is made and how the blocking, grinding, polishing, centering, coating, mounting, finishing, and testing are done. *Who cares?* Several different classes of people care about 25 minutes' worth, we hope. For examples: 1) youngsters with a healthy curiosity about the various basic technologies that underlie our civilization; 2) engineers and businessmen sufficiently catholic in their interests to realize that it often pays to watch over another fellow's shoulder if he's willing and seems to know what he is doing; 3) professional photographers and amateur camera fans who want to see how good lenses are made. *How is this film booked for showing?* By a note to Eastman Kodak Company, Camera Club and School Service, Rochester 4, N. Y., to give us an idea of what folks will be in the audience and what organization will assume responsibility for sending the film back to us in good shape. The title is "Quality in Photographic Lenses." There is no rental charge.

Isobutyraldehyde

A chemical plant is a fancy plumbing job animated by an idea. We have one at Longview, Texas, animated by this idea:

$$CH_3CH{=}CH_2 + CO + H_2 \rightarrow CH_3CH_2CH_2CHO + (CH_3)_2CHCHO$$

In words, natural gas, refinery by-product propane, and steam are turned into butyraldehyde, normal or iso. (This is known as the Oxo Process.)

Right now the valves are set for a certain ratio of normal to iso. The ratio depends on the relative demand, both internal and external. We have a very strong and ever-growing internal demand for compounds that start from n-butyraldehyde. The isobutyraldehyde, perhaps reduced to isobutyl alcohol or oxidized to isobutyric acid, leaves our hands at an earlier stage in its career. The iso aldehyde, alcohol, and acid are all points of departure for a great variety of interesting reactions. Most of these are of more industrial importance to other companies than to us. We should like to make certain that all of their voices

have been heard before deciding that our setting of the valves is economically correct.

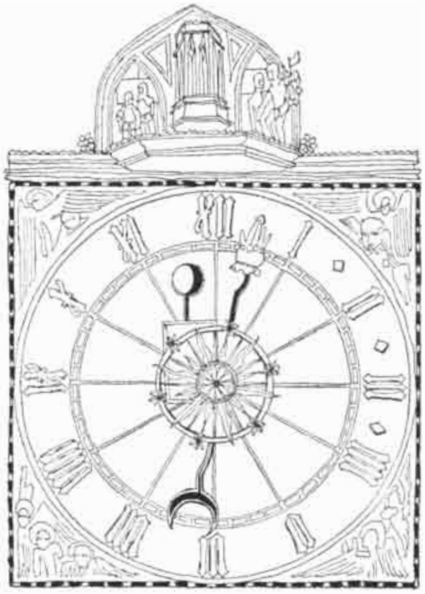
One of the principal ways the chemical industry grows is through the posing of questions like this. A reaction becomes practical that was impractical before because one of the reactants is more abundant than it had been. Somebody is likely to make money as a result. The key is communication. A usual vehicle for such communication is a comprehensive treatise in which the seller sets out all the chemical facts he can assemble about his offering and then awaits developments. This is where we now stand in respect to isobutyraldehyde.

If you can see enough connection with your problems to send for a free copy of "The Chemistry of Isobutyraldehyde and Its Derivatives," the first stone in a landslide of events may be rolling now. Write Eastman Chemical Products, Inc., Chemicals Division, Kingsport, Tenn. (Subsidiary of Eastman Kodak Company).

This is one of a series of reports on the many products and services with which the Eastman Kodak Company and its divisions are . . . *serving laboratories everywhere*

Kodak TRADE-MARK

SCIENCE AND



Total Danger

In the vast, lonely wilds of the Pacific Ocean, far—but not far enough—from civilization, man was at last playing last month with forces sufficiently powerful to destroy the human race with satisfactory speed. From behind the "security" curtain around the test area came reports of explosions which astonished scientists and satisfied even the military—of islands decapitated, of immense craters blown in the ocean floor, of fireballs large enough to engulf a city, of shock waves thunderous enough to travel around the globe. Among all the phenomena, nothing kindled more terror in the hearts of the peoples of the earth than a gentle rain of burning ash that fell from the blue upon 23 men peacefully going about their business in a Japanese fishing boat. The Thermonuclear Age fell upon mankind without mercy, if not entirely without warning.

The shock wave of fear brought its train of panic—but as yet only a small-sized panic. Mixed with the fear there were still large portions of complacency and incredulity. Yet there was a rising demand for information which could not long be denied. Just as war is too important to be left to the generals, so the Thermonuclear Bomb had become too big to be entrusted any longer to the executive sessions of rulers or technicians. If the means of doom for mankind had become a reality, the population at least wanted to know how and in what form that doom might come.

The surface events were but a faint echo of what had really happened; after the bang there came only whimpers. On March 1 the Atomic Energy Commission announced that it had just made another "routine atomic test" at its explosion grounds in the Marshall Islands. Soon came reports that it was something more than routine. A Marine corporal on Kwajalein, nearly 200 miles from the test at Bikini, wrote home to his mother that the blast had shaken his barracks like an earthquake. The AEC announced that 28 of its observers and 236 natives on islands scores of miles from the test had been showered with a radioactive "fallout." Congressmen began to inform reporters that the explosion had been three or four times as large as expected, that it had got "out of control." It was said to be far larger than the first thermonuclear experiment in November, 1952, which had blown an island from the face of the sea. Its power was reported equivalent to 12 million tons of T.N.T.—600 times as forceful as the Hiroshima atomic bomb. Its radius of total destruction might be 10 miles or more; its blast wave of sound was detected by far-off British monitors.

The immediate brunt fell on a Japanese fishing vessel called *The Fortunate Dragon*, carrying a harvest of tuna and shark in its open hold. Caught 80 miles from the explosion, it was showered with a white ash of particles which blistered the 23 fishermen's skin and made the fish radioactive. When the ship made port, some of the fish were sold before the government could stop it. Overnight the Japanese people stopped eating fish; housewives shopped with Geiger counters; the price of tuna fell to one third with few takers. As for the fishermen, Professor Masao Tzuzuki of Tokyo University and others who examined them found that they had inhaled and swallowed radioactive fission products. The Japanese doctors predicted that some of the victims would die. The Japanese newspapers looked upon the shower of "death dust" as the third atomic bombing of Japan. Government officials and the Japanese people demanded an international ban upon all atomic weapons and control of atomic energy. The great Japanese physicist Hideki Yukawa said sadly: "Atomic power has grown up like a ferocious animal its master cannot completely control. The issue appears to transcend differences of social systems and to concern the very fate of the human race itself."

Premier Malenkov of the U.S.S.R.

had voiced much the same conclusion, acknowledging to the Soviet people for the first time that atomic war would mean "the destruction of world civilization." In India Prime Minister Nehru urged the U. S. to end its hydrogen bomb experiments. He likened the new weapon to "the genie that came out of the bottle, ultimately swallowing man." And in Great Britain 104 members of Parliament signed a petition calling for control of all nuclear weapons by the United Nations and immediate cessation of the hydrogen bomb experiments. Lord Hore-Belisha, returning to Parliament from a 10-year retirement, said solemnly: "I want to know, and I am sure the country does, too, in what conditions the U. S. are going to use the atomic bomb." Prime Minister Churchill, called up for a full-dress questioning by the House of Commons, brokenly told the stern House that he was in "almost hourly correspondence" with the U. S. Government but had been unable to obtain the facts about the new weapons because of the secrecy strictures in the U. S. Atomic Energy Act. "I am sure," he added, "that the American people are equally anxious to be informed."

On March 26 the AEC and its military associates set off the second thermonuclear explosion in the "current series." For this one they had cleared several times as large a danger area in the Pacific—nearly half a million square miles—ignoring British and Japanese cries of violation of "the freedom of the seas." Chairman Lewis L. Strauss of the AEC witnessed the test and hastened to Washington to deliver a report for which Congressmen and the public were clamoring. Standing beside President Eisenhower at a press conference, Admiral Strauss endeavored to reassure the nation. The reports of the thermonuclear explosions, he said, had been "exaggerated." The "yield" had been about twice the estimate—"a margin of error not incompatible with a totally new weapon." No large island had been blown up—only small sand bars. *The Fortunate Dragon* had been the victim of an unfortunate wind shift; its fishermen's wounds were probably not due to radioactivity but chemical burns caused by lime particles from the blasted coral; the Japanese had not allowed U. S. doctors to examine them; the U. S. was prepared to indemnify the victims. There was no evidence of widespread contamination of fish in the Pacific. He had visited the showered island natives and found them apparently "well and happy." As for the tests themselves, they had been successful; "the results which the scientists at Los Alamos and Livermore had hoped to obtain . . . were fully realized," and the U. S. could be assured that it was keeping pace with the Russians, who "had begun work on this weapon substantially before we did." Admiral Strauss concluded that the hydrogen bomb development had enhanced "our military capability to the point where we should soon be more free to increase our emphasis on the peaceful uses of atomic power."

But the peaceful use of atomic power was not the thing that was on everyone's mind. A reporter asked how destructive the bomb would be.

Admiral Strauss: "An H-bomb can be made large enough to take out a city."

Question: "How big a city?"

Admiral Strauss: "Any city."

Question: "New York?"

Admiral Strauss: "The metropolitan area, yes."

Released next day was a film of the November, 1952, shot, which by comparison with the 1954 successes must be counted a thermonuclear fizzle. The explosion (fission plus a little fusion) disintegrated an islet half a mile long, left a hole more than a mile in diameter and 175 feet deep and created a fireball three and a half miles in diameter. The estimated radius of annihilation was three miles; of damage, 10 miles.

It seemed that H-bombs would be comparatively cheap, perhaps composed of lithium and deuterium or some such combination, and not difficult to manufacture. In their New York *Herald Tribune* column the Alsop brothers divulged, however, that physicists foresaw a limit to the effective power of the H-bomb: beyond about 50 megatons (the power of 50 million tons of dynamite) the blast could spread no farther sideways and would blow clear through the roof of our atmosphere—"the limit of blowout." The H-bomb's limitations of range are not, however, irreparable; the New York *Times* science reporter William L. Laurence quickly pointed out that the addition of a cobalt shell could sow lethal radioactivity over a continent.

In the dazed City of New York the Civil Defense Director, Herbert O'Brien, said in despair: "Air-raid shelters are obsolete." The only hope would be to flee the city—but New York would need at least three days' warning of a raid to evacuate its population in time. Val Petersen, the U. S. National Civil Defense Administrator, had no better prospect to offer. "The cities," he said, "are finished." He had made a survey of the probable toll of a thermonuclear attack on the major U. S. cities, and had concluded that at least nine million people would be killed. "Just as a practical matter," he observed, "how in hell are you going to bury nine million corpses?"

U. S. Senator Stuart Symington expressed the frozen state of mind of people throughout the world: "We are now in that era some of us have predicted with dread for a long time—the period of total danger."

No realistic statesman was lulled by the notion that the H-bomb automatically made war improbable. In the House of Commons Clement Attlee said: "We have only recently seen a great nation, Germany, putting all its resources in the hands of a paranoiac. Who can doubt, after reading of Hitler's last days, that even at the very end of that war if he had had the atomic bomb he would have used it? There is no guarantee that in some country at some time there may not arise to power a fanatic. . . . The only way open to us seems to be to make a new approach to world problems. . . . It is not too late."

Reactors

The Atomic Energy Commission last month announced a $200-million, five-year program for developing nuclear power reactors. The Commission has selected the five most promising lines of approach and will build reactors to explore each of them. One of the reactors is to be a full-scale model producing 60,000 kilowatts of electricity; the others will be smaller, experimental devices.

The full-scale plant is the pressurized water reactor (PWR) described in the Commission's last semi-annual report (see "Science and the Citizen," Scientific American, March). It will cost $85 million. Although it is considered the poorest "long-term prospect" for making economic power, it is the only design about which enough is now known to justify building a full-scale model. Experience gained from its operation is expected to apply to more promising types.

The Duquesne Light Company of Pittsburgh has agreed with the AEC to operate the reactor as part of its regular power net. The utility is to provide the site and the electric generating plant, to pay $5 million toward the reactor itself and to pay all operating expenses—a total estimated investment of $30 million.

The other reactor types to be built, in the order of the promise they are con-

sidered to show, are: the homogeneous reactor—combining fuel, moderator and coolant in a single solution; the fast breeder; a new "boiling water reactor;" the sodium-graphite reactor.

Two homogeneous reactors are scheduled. The first, slightly larger than the small experimental model now operating at Oak Ridge, is intended to prove that such a device can operate reliably over a long period. It will include equipment for continuous chemical processing of the fuel. The second model is to be much larger (16,000 kilowatts of electricity). It will test the feasibility of breeding U-233 in a thorium blanket around its core. The Commission explains that conversion of thorium to U-233 is best done in a slow neutron reactor such as the homogeneous type, whereas the breeding of plutonium from U-238 is most readiiy achieved in a fast reactor.

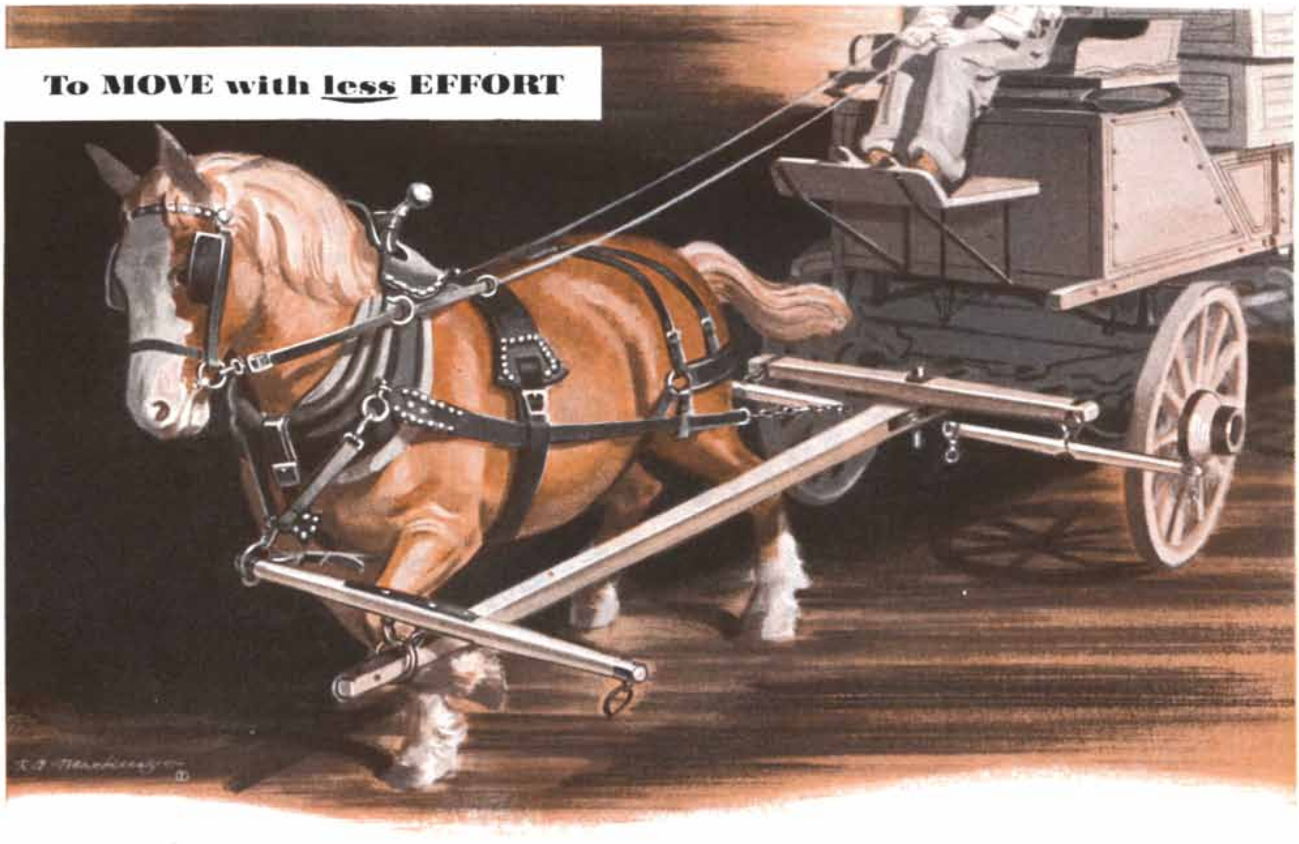
The new fast breeder will be rated at 15,000 kilowatts. It is to use U-235 fuel at first and then plutonium, said to be more efficient for breeding.

The new boiling water reactor is an outgrowth of some safety experiments done last summer by Walter H. Zinn, director of the Argonne National Laboratory. In an effort to find out what would happen to a water-cooled reactor if it were to overheat accidentally, Zinn designed a small reactor in which the control rods could be withdrawn suddenly so that the power would rise quickly to a very high level. At a high power level he found that, as he had hoped, the reactor controlled itself. The water coolant boiled and the steam quenched the chain reaction before the temperature could rise to a dangerous height. The reactor was successfully operated while boiling continuously. Zinn believes that the steam generated in this way could be piped directly to a turbine, eliminating the need for a heat exchanger.

Plans for a sodium-cooled, graphite-moderated reactor have been drawn up by North American Aviation, Inc. It will be fueled by enriched uranium or thorium mixed with U-233, and is expected to produce about as much new fissionable material as is burned. The sodium coolant will give the advantage of high temperature without high pressure. The reactor is designed to operate at temperatures of more than 1,000 degrees Fahrenheit.

New Atomic Energy Law?

The Administration bill to amend the Atomic Energy Act was finally introduced in Congress by Senator Bourke B. Hickenlooper and Representative W.



You need only half the horsepower

with our screw that rolls on balls


Cutaway view of ball-screw mechanism

There's a lot of difference in size and weight and electrical requirements... *and* cost...between a 4-horsepower and an 8-horsepower motor.

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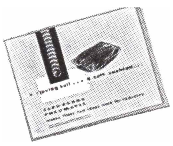

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Cutaway of shock-absorber mechanism →

Sterling Cole last month. It goes considerably beyond President Eisenhower's recent general outline of recommendations. Among the major changes proposed are:

Authorization of the Atomic Energy Commission to license anyone to own and operate facilities for producing fissionable or other "special" materials.

Removal of all restrictions upon granting patents except for atomic weapons.

Abandonment of the Government's right to reserve possession of uranium and thorium deposits in public lands that may be sold or leased to private parties.

Authorization of the President to give information on atomic technology and military uses to any nation which does not threaten the security of the U. S. No data on atomic weapons themselves is to be disclosed except their "size, weight and shape."

Five Billion Volts

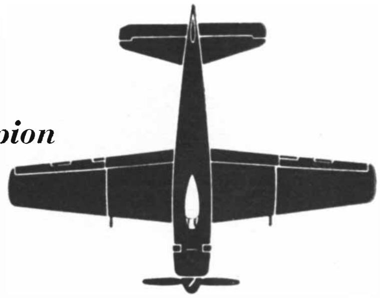
The University of California's Bevatron, biggest atom smasher in the world, went into operation last month. In its early trials it accelerated a beam of protons to an energy of five billion electron volts (Bev). The giant machine, which has been five years building, is designed for a maximum energy of 6.5 Bev. It is a proton synchrotron, similar to the Brookhaven cosmotron, but five times as massive and slightly more than twice as powerful. With the Bevatron, physicists expect to produce heavy mesons, which are now found only in cosmic rays. They may also be able to decide whether antiprotons (negative protons) exist.

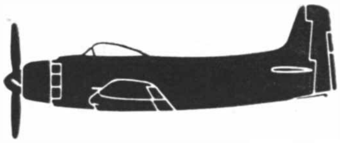
The Bevatron's 10,000-ton magnet encloses a circular track 120 feet in diameter which the accelerating particles traverse some four million times in reaching five Bev. Before entering it the protons have been speeded up to 10 million electron volts by an electrostatic accelerator and a linear accelerator. An "inflector" steers them into the Bevatron track at just the proper angle. A high-frequency oscillator boosts the particles' energy by 1,300 electron volts each time they make a circuit. The machine operates in pulses, producing 20 bursts of protons per minute, each burst containing about 100 million particles.

The Bevatron was financed by the AEC at a cost of $9 million. It was designed by William Brobeck, assistant director of the California Radiation Laboratory. Lloyd Smith, the physicist who made the theoretical computations for the design, described the machine in an article in SCIENTIFIC AMERICAN of February, 1951.

Newest version of the

world's single-engine weight-lifting champion





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Now comes the newest version of Skyraider—the Douglas AD-6. A hint of its efficiency can be seen in the world record set by its predecessor, the AD-4, which recently took off with a useful load of 14,941 pounds—*three thousand pounds more than its own basic weight.* Most versatile planes in the air, the AD Skyraiders can handle 22 different assignments—a usefulness which will be extended even farther by the new AD-6.

Development of the AD-6 Skyraider is another example of Douglas leadership in aviation. The development of planes that can be produced in quantity—*to fly faster and farther with a bigger payload*—is the basic rule of Douglas design.

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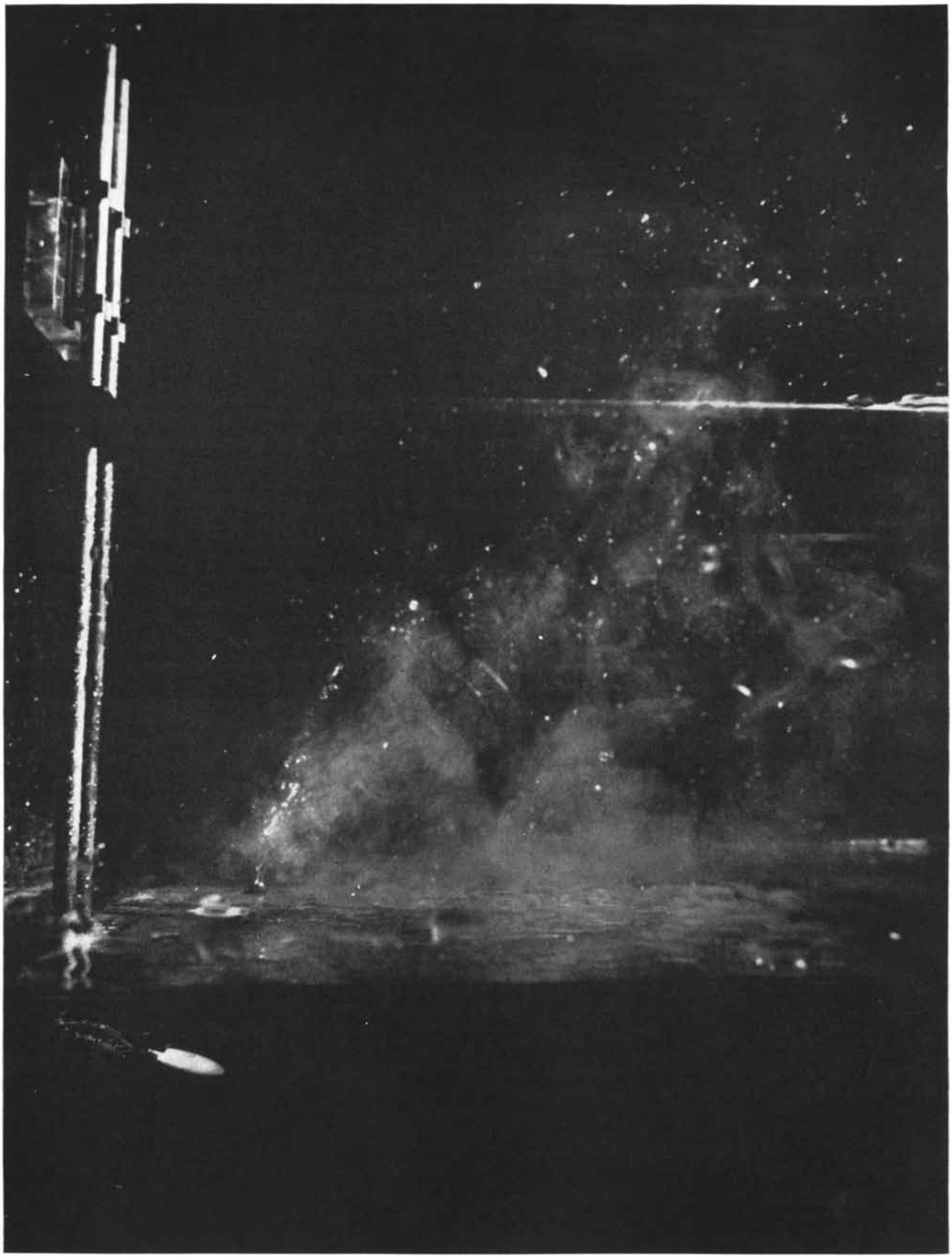


FOUNTAIN OF WATER AND FOG is projected from the surface of water in a glass tank by an ultrasonic beam focused at the surface. The ultrasonic vibrations are produced by the ceramic disk at the lower left. The disk, made of barium titanate, is caused to vibrate at two and a half million cycles per second by a current supplied by the two electrodes coming down from the upper left.

ULTRASONICS

Sound too high for human hearing has a peculiar fascination which perhaps explains why so much is expected of it. If its applications are few, they are impressive and promise others

by George E. Henry

The range of sounds audible to the human ear is from 20 to about 20,000 vibrations per second. This is sonic sound; all sound waves above the audible range—specifically, frequencies higher than about 18,000 or 20,000 cycles per second—are called ultrasonic. In the picturesque language of the acoustical engineer, sound covering the range of audible frequencies is known as "white noise," just as white light means a mixture of all wavelengths of visible light. Extending the analogy, we might call ultrasonics "black noise," as we say "black light" for ultraviolet.

Before getting into the subject of ultrasonics we need to clear up the confusion that still surrounds the word. Sound above the audible range was originally called supersonic, but that word was appropriated by the aerodynamicists to describe speed beyond the velocity of sound. The whole difficulty has now been resolved by common agreement on the definitions of the prefixes. "Super" and "sub" refer to velocity; "ultra" and "infra," to frequency. Thus a child on a swing oscillates at infrasonic frequency, and moves, of course, at subsonic speed. A jet-propelled airplane may travel at supersonic speed, but the acoustic output of its engines, as any listener will testify, is not ultrasonic.

Another source of confusion is that many people mistake high frequency for high power. In the popular mind ultrasonics is identified with balls of cotton bursting into flame or bits of cork floating in a high-pressure sound field. People speak of "ultrasonic smoke precipitators," when in fact these machines operate well within the sonic range. A few years ago an Australian firm advertised an "ultrasonic" home laundry machine which actually agitates the wash at 100 or 120 cycles per second. High intensity or power does not mean high frequency, or *vice versa*; power and frequency are, of course, fundamentally independent of each other. The confusion arises from the fact that only at high frequency is high power attainable economically.

We shall consider two main classes of ultrasonic applications, roughly distinguishable as those of low power and of high power. In the first class are instruments which perform measurements; they inspect, detect, diagnose and report or control. Machines of the second class change the physical or chemical state of the material on which they operate. The distinction is analogous to that between the use of X-rays for making pictures (*e.g.*, of a bone fracture or a misplaced safety pin) and for treating a tumor.

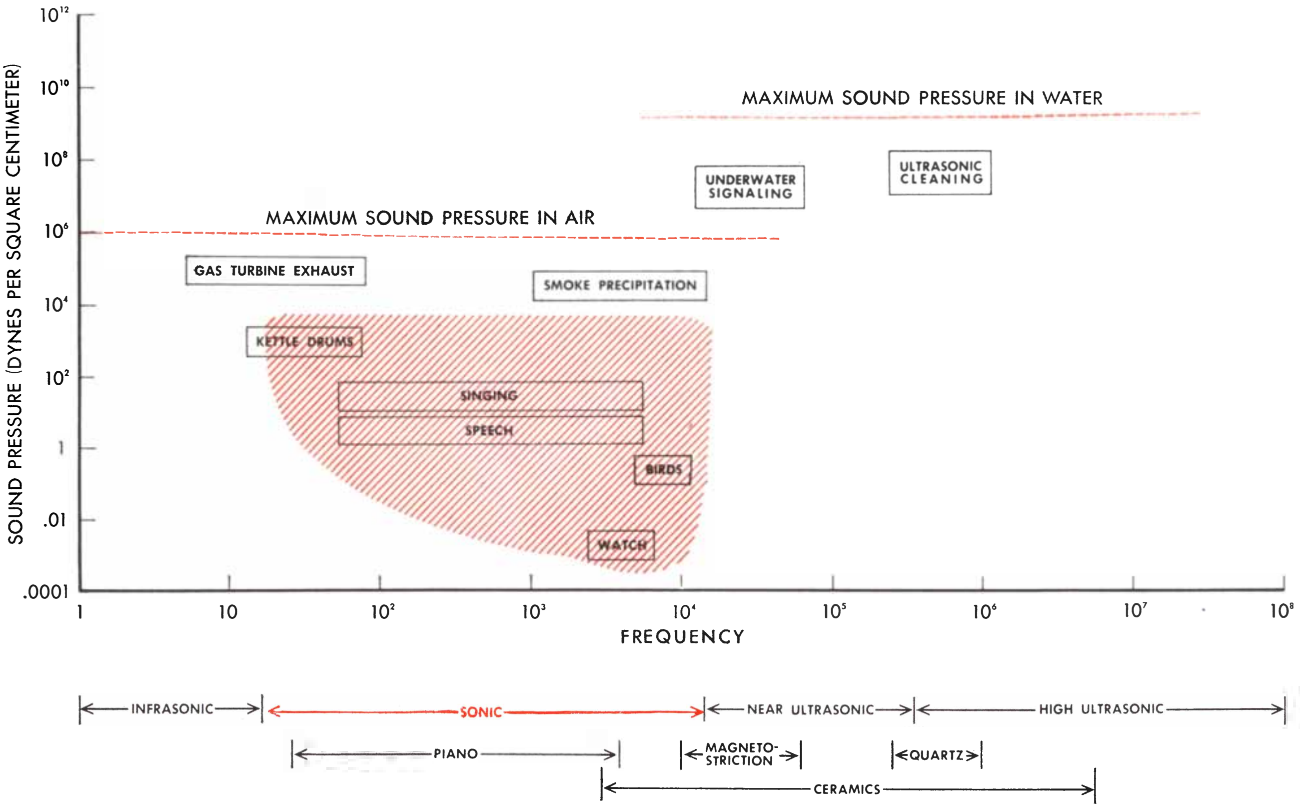
The Interferometer

Ultrasonic instruments of the first class are now widely known and understood. They were first on the scene and until very recently received most of the attention. An excellent example is the ultrasonic interferometer for measuring the velocity of sound in fluids. The wavelength of ultrasonic sound is short enough to reduce the measuring equipment to convenient and economical size. The ultrasonic interferometer has advanced us somewhat beyond the combination of stop watch and artillery which was the favorite resource of the French Enlightenement for investigating the speed of sound.

A typical interferometer is shown in the diagram on page 57. The source of the ultrasonic sound, called the transducer, is a crystal or ceramic vibrator. Voltage from a vacuum-tube oscillator impresses opposite and alternating electric charges (positive and negative) on the top and bottom faces of the slab. When the upper face is made positive and the lower face negative, the slab becomes thicker. When the charges are reversed, it becomes thinner. These changes take place rapidly, as often as several million times per second.

Behaving like a piston, the upper face of the crystal transmits its vibrations to a liquid or gas in the chamber. The process enables us to understand what a sound wave really is. We may regard the crystal face as a portion of the floor of a tank containing liquid or gas. As the "floor" moves upward, the layer of fluid adjacent to it is compressed, because the next layers beyond, possessing inertia, do not have time to move. The compressed layer then tends to expand back to its original thickness. In so doing it compresses the second layer, and so on and on. If the fluid is perfectly elastic, and if the pressure wave is prevented from spreading sideways, all the higher layers of fluid will be compressed, in their turn, just as much as the first layer was.

The pressure wave is really a store of potential energy being passed rapidly from layer to layer of the fluid. The compressed fluid's molecules also are given kinetic energy, which moves along from layer to layer in phase with the potential energy. Together the alternating pressure and the alternating motion of the molecules constitute a sound wave. The wave will travel through layer after layer in a perfectly uniform fashion, so long as the properties of the material remain unchanged. But when the wave encounters a material of radically different acoustic properties, it is reflected. In the case of our interferometer, this happens when the wave strikes a smooth metal reflector plate a few centimeters above the crystal. Now the reflected waves mingle with the oncoming ones and a "standing wave" system comes into being. It is a peculiar-



SPECTRUM OF SOUND is depicted in two dimensions by the chart at the top. The intensity and frequency of several sonic phenomena are roughly located by labeled boxes. The colored area indicates the sound audible to human ears. The first set of arrows below the chart divides the realm of sound into four provinces. The bottom set indicates the ranges of some sound-producing devices.

ity of standing waves that the pressure fluctuations and particle motions no longer go along together but occur at different places, separated by a regular interval of one quarter wavelength.

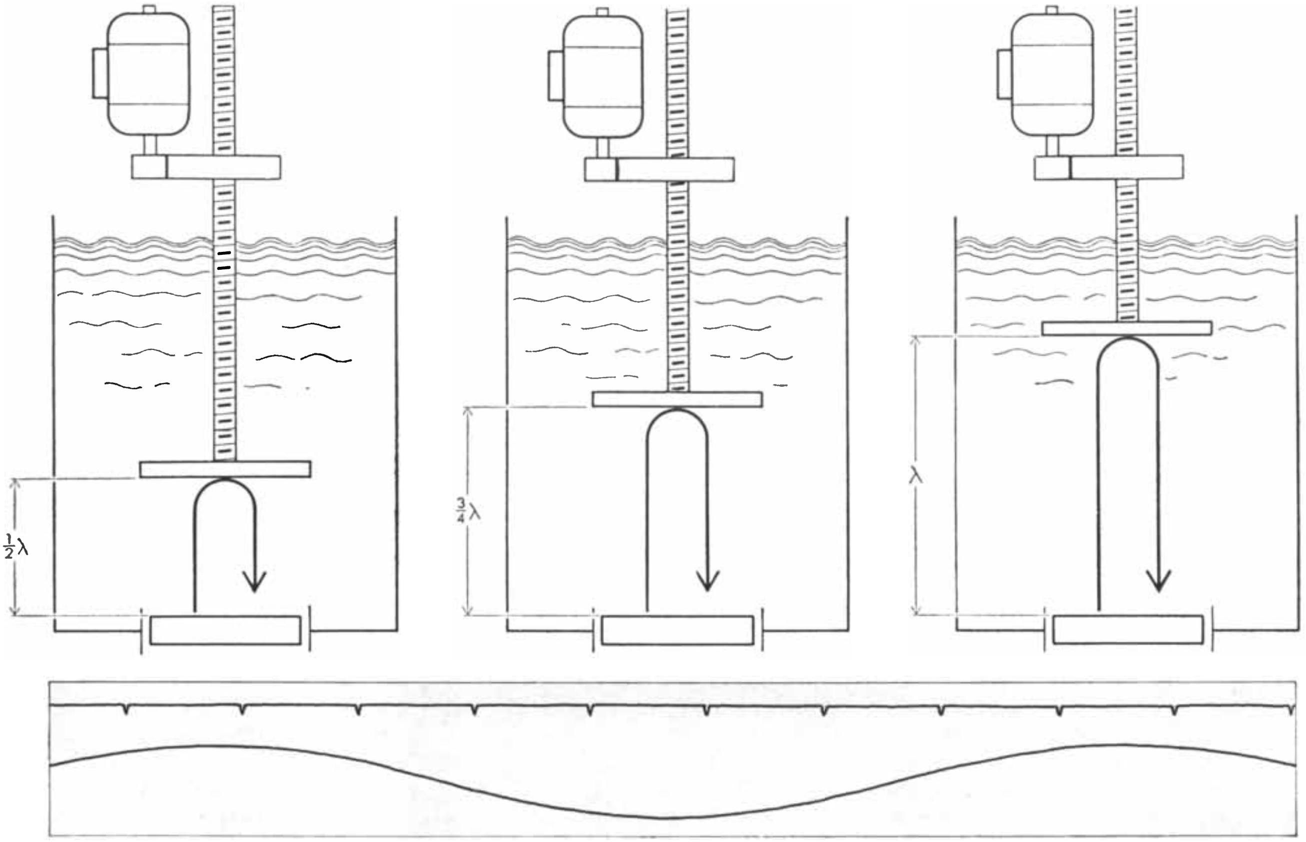
Our interest is centered on the phase relation between the outgoing and the returning (reflected) waves. This relation determines the reaction of the fluid to the motion of the vibrating crystal. If the outgoing and returning waves coincide in phase, the augmented pressure will tend to limit the free motion of the crystal. Contrariwise, if they are out of phase, so that the updriving face meets a rarefaction (low pressure), it will move farther than usual. Now the interesting part of all this is that the electrical characteristics of the crystal are influenced by the amount of constraint imposed upon its motion. The net result is that the voltage across the crystal must vary according to the varying pattern of the mechanical load.

If the distance between the crystal and the reflector is slowly increased, one can obtain a regular succession of the in-phase and out-of-phase conditions, and these are recorded as peaks and valleys of voltage across the crystal. From the voltage curve it is then easy to calculate the length or the frequency of the ultrasonic waves. The frequency fed to the crystal can be controlled to within one fourth of 1 per cent or better, and the wavelength can be measured with at least comparable precision by continuing the traverse of the reflector through an ever larger number of peaks and valleys.

When the wavelength is less than one millimeter (corresponding to a frequency of two million cycles per second or higher), the number of peaks and valleys swept through can be very large indeed. As the reflector creeps slowly away from the crystal, the recorder pen wags monotonously from side to side, repeating over and over what at first appears to be a perfectly uniform harmonic motion. But after a time we notice a difference—the amplitude of the curve grows smaller. This shows that the sound wave and its reflection, now traveling a longer path, have become weaker; the reflection therefore has less effect upon the movement of the crystal. The weakening, or attenuation, is due partly to spreading of the beam and partly to absorption of the sound energy by the fluid—that is, the conversion of sound (orderly motion of molecules) into heat (disorderly motion of molecules).

Ultrasonics and Molecules

The rate of absorption of sound by fluids, particularly by gases at low pressure, is of great interest to physical chemists. Classical theory, formulated during the 19th century, held that the absorption rate, or conversion of sound into heat, must increase with the square of the frequency. But measurements with the interferometer indicate that above 50,000 cycles per second important modifications of this theory become necessary; the rate of absorption varies with the frequency in a rather irregular fashion and is generally greater than the theory predicts. It is not enough to consider the kinetic energy of the molecules' travel; kinetic energy may also be stored in their own internal motions—rotation of the molecule around its own axis or vibratory motion of the atoms in the molecule. When the sound vibrations are of a frequency at which molecules can absorb energy internally, we get "super-classical absorption." Experiments on carbon



INTERFEROMETER can be used to measure the wavelength of ultrasonic vibrations. At the bottom of this tank is a vibrating crystal. If the position of the reflector above the crystal is at an interval of half a wavelength (*Greek letter lambda*), the voltage across the crystal increases. If the position of the reflector is at an interval of a quarter wavelength, the voltage decreases (*see curve*).

dioxide have yielded values of absorption several hundred times larger than classical theory predicts; at high frequency, indeed, this gas is described as acoustically opaque. Only the noble gases—helium, argon and the like—which contain but a single atom per molecule, behave acoustically approximately as they should according to the classical theory.

Closely associated with super-classical absorption is the related discovery that the velocity of sound varies with frequency and with pressure. Generations of school children have learned that sound velocity does *not* vary with frequency. One proof offered is that band music heard at a distance is still synchronized, the tubas right with the piccolos! At sonic frequencies and biogenic pressure the rule holds. But at 15 million cycles per second per atmosphere it definitely does not.

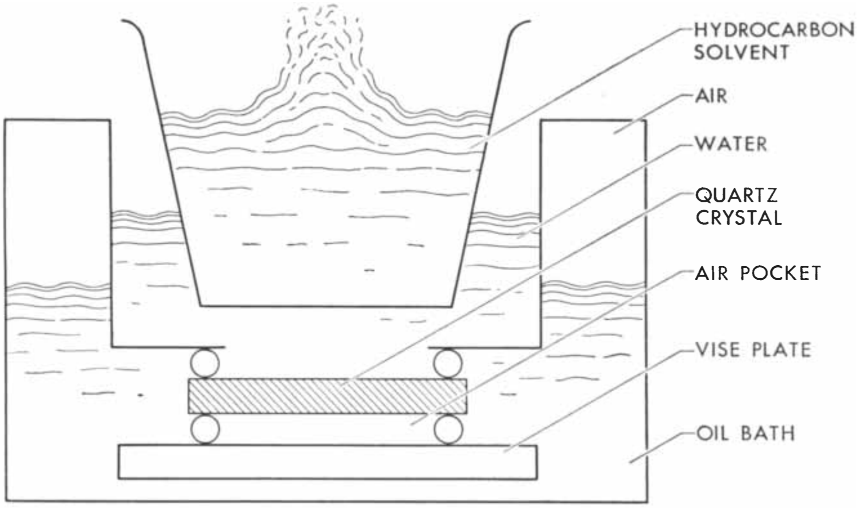
Applications

High-frequency sound, like high-frequency radio, offers a convenient means of producing pulsed signals. They have been put to several important uses. Among these is a now standard instrument, called the reflectoscope, for detecting hidden cracks, bubbles or other flaws in a metal. A quartz crystal is pressed against the surface of the metal. From the crystal a short burst of sound travels into the specimen in a well-defined beam. If it encounters a crack or an air bubble, it is reflected from that region, and the time interval for the return of the echo locates the defect. If the specimen is perfect, the signal does not bounce back until it reaches the opposite surface of the metal.

Commercial and military sonar equipment employ the pulse-echo-ranging principle to chart the ocean bottom and to locate schools of fish, hostile naval craft, derelicts and other hazards to navigation. However, the early hope of being able to detect icebergs by sonar has so far failed to be realized. The reason for the failure harks back to acoustic fundamentals: water and ice have nearly the same density, and sound travels at nearly the same speed through both. Hence a sound wave passes freely from one medium into the other with only a small amount of reflection at the boundary.

Could sound devices be developed to locate objects in darkness or fog? The answer is a qualified negative. The futility of a sound wave (whether sonic or ultrasonic!) in quest of an airplane moving at Mach number 2 is pathetically apparent at the outset. Moreover, the attenuation of sound with distance is much greater in gases than in water. The radar men need lose no sleep over competition from this quarter, except, perhaps, in the special case of spotting slow-moving bodies at distances of 100 feet or less.

In sonar the advantage offered by the ultrasonic frequency range resides not only in the fact of short wavelength, but even more importantly in the possibility of using very brief pulses. Short bursts of sound are possible only at high frequencies. The reason for this can be well appreciated if we think again of what frequency really means—cycles per second. A brief pulse of low frequency would contain very few complete cycles, perhaps not even one complete cycle; this would make it difficult or impossible to identify the frequency precisely by any process of counting the peaks and valleys occurring within the specified time interval. Instead of a clear, sharp signal we



ULTRASONIC GENERATOR for cleaning purposes has this arrangement of parts. The oil acts as an insulator, preventing high-voltage arc-over around the edge of the crystal.

would have a somewhat patternless disturbance difficult to separate from the random background noise of marine life, water currents and thermal-electrical impurities in the sonar mechanism itself.

There is another property of high frequency, which, like short wavelengths and brief pulses, makes it admirable for fine-grain measurement. It is the short stroke, or displacement amplitude, of the particles in the wave. This characteristic finds an ideal application in a new device for measuring viscosity. The sense organ of the instrument is a thin blade, driven back and forth in the test liquid like a table knife opening a biscuit. It travels only a few millionths of an inch, at 25,000 cycles per second. In a liquid such as petroleum virtually the only impediment to the free motion of the blade is viscous drag; the gross motions of molecules do not affect it. This drag is sensed as extra load on the vibrating source. Hence it is measurable in terms of the electrical input to the source, much as in the case of the interferometer.

When the signal has been converted to voltage and conducted to the grid of an amplifying tube, it can be employed in any number of ways. A sophisticated application is to make it control the machine that governs viscosity, perhaps by adding diluent to the batch of liquid under test. Indeed, this automatic-control feature is applicable in a number of ways to most of the instruments so far discussed; an interferometer, for example, can control the molecular weight of a gas mixture by governing the rate of inflow of its constituents, preserving always a fixed relation between the velocity of sound and the temperature of the composite fluid.

So much for the first part of the story—ultrasonics for measurement, signaling, exploration or control. Its methods are refined, and its power levels (except for certain sonar equipment) generally low.

High Power

The scene changes abruptly as we pass on to acoustic processing. Here power is the *sine qua non.* Often the desired effect appears to take place only when the power is raised above some threshold value, and this value may be very high. Now the transducer—the device used to convert electrical energy to acoustic energy or *vice versa*—must be matched to its load. A quartz crystal is capable of exerting large forces but incapable of stretching far out of its original dimensions. Hence it cannot possibly create high acoustic intensity in gases, which offer only small resistance and need to be agitated at high velocity in order to store or transmit much energy. The crystal would vibrate almost unimpeded; it would be ineffective for the same reason that a sledge hammer is an ill-chosen tool for moving feathers.

High-energy sound in air is best produced by whistles and sirens. Pioneer studies at the Bell Telephone Laboratories and at the Pennsylvania State College have led to the development of very good sirens indeed. These expensive, precision-built, high-speed machines send out a beam of sound which will kill a small animal within a few minutes (and is potentially dangerous to human beings as well). There are definite limitations, however, to the output of these devices—limitations which are inherent in the nature of sound itself, and of the atmospheric ocean in which its effects are most often perceived.

The frequencies available from such a

SMALL GENERATOR of the type illustrated at the upper left is demonstrated with two squares of steel. The clean piece of metal at left was dipped in the solvent only momentarily.

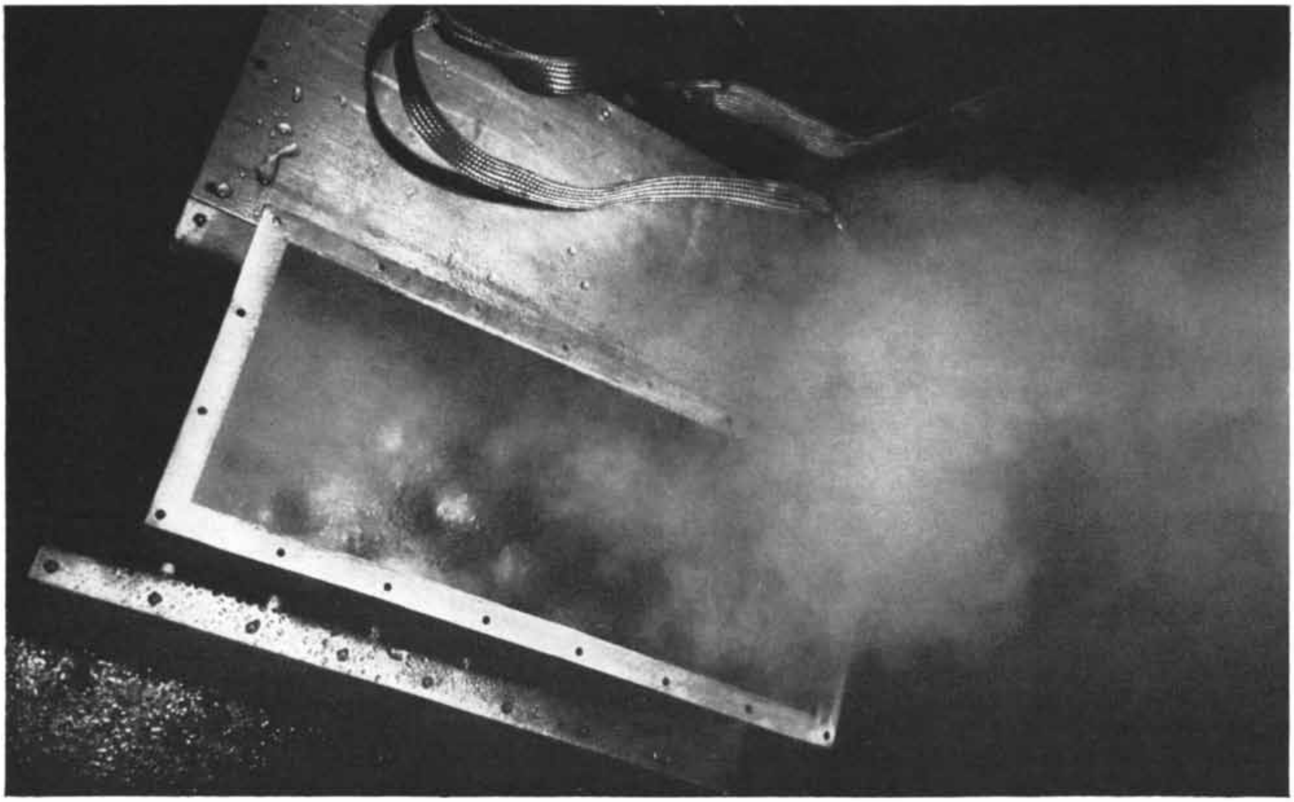
source are limited by several considerations, of which two are especially important. First, as the frequency goes up the loss of power by absorption in the air increases rapidly so that a couple of yards away it is nowhere near its original value. Second, most sirens today are driven by electric motors, and to reach the ultrasonic range the motor must rotate very rapidly. If we choose to follow experimenters at the Pennsylvania State College and build a siren disk having 100 air holes or slots, then we must spin the rotor at 200 revolutions or more per second to produce ultrasound safely above the hearing range. It becomes apparent that any siren intended to deliver high power at a frequency as much as three or four octaves above the usual 20,000 c.p.s. would present an extraordinarily difficult design problem. In practice, therefore, only a small part of the ultrasonic range is actually available for high power in gases.

Fortunately this restriction is not unduly troublesome from the application point of view. The characteristic industrial use of high-energy airborne sound is that of precipitating smoke or dust in exhaust stacks, and this process, as mentioned earlier, is most successful at low frequencies anyway. Other uses may be found, but none is currently of any widespread importance. Some people, indeed, will say that smoke precipitation isn't very important either, for there has been a conspicuous decline in announcements of new installations since the late 1940s. This apparently promising device runs into the law of diminishing returns. As the agglomeration of particles in the air proceeds, the performance of the machine becomes more and more inefficient, for the same energy is expended on less and less material. This seems to say that the best field of application for smoke precipitation will be found in those instances where the chief purpose is to recover the suspended material, rather than to purify the gas.

Commercially successful or not, smoke precipitation is an interesting phenomenon physically. Several different mechanisms are involved in the process of particle agglomeration. One of the first to receive attention and recognition is the so-called principle of co-vibration—an effect due to the relative motion between large and small particles suspended in a sound field. A very small particle will tend to rock to and fro in the field, sharing, to some extent, the wave motion of the air molecules themselves. Larger particles, however, will not move very much; they will barely get started moving in one direction before it is time to go the other way. This difference in absolute amplitude, combined with a difference of phase, adds up to a measurable difference of motion between large and small particles. Accordingly they collide, if properly aligned and close enough together to begin with. Upon collision they stick.

Less obvious in its working but more important to the final result is the migration of heavy bits of material to the pressure-nodal planes in a standing wave system. This action can be demonstrated in a spectacular manner. With a whistle and reflectors one can make bits of cork or paper float in formation, as neatly spaced as the rungs of a ladder [*see photograph on page 62*]. The advent of the high-power siren has improved the demonstration: coins and glass marbles can be held in the air in equilibrium between the forces of gravity and of sound radiation!

How much power does all this require? Let us look first at the condition fixing the upper limit of attainable power —the pressure of the earth's atmosphere. Sound is a fluctuation in pressure above and below this level. In all but the loudest sounds the fluctuation in pressure is quite small compared to the fixed atmospheric pressure. A pressure variation amounting to only one tenth of an



LARGE GENERATOR has 15 vibrating crystals. Such a machine could be used to clean parts on a conveyor belt. Both this generator and the one on the opposite page were photographed in the General Engineering Laboratory of the General Electric Company.

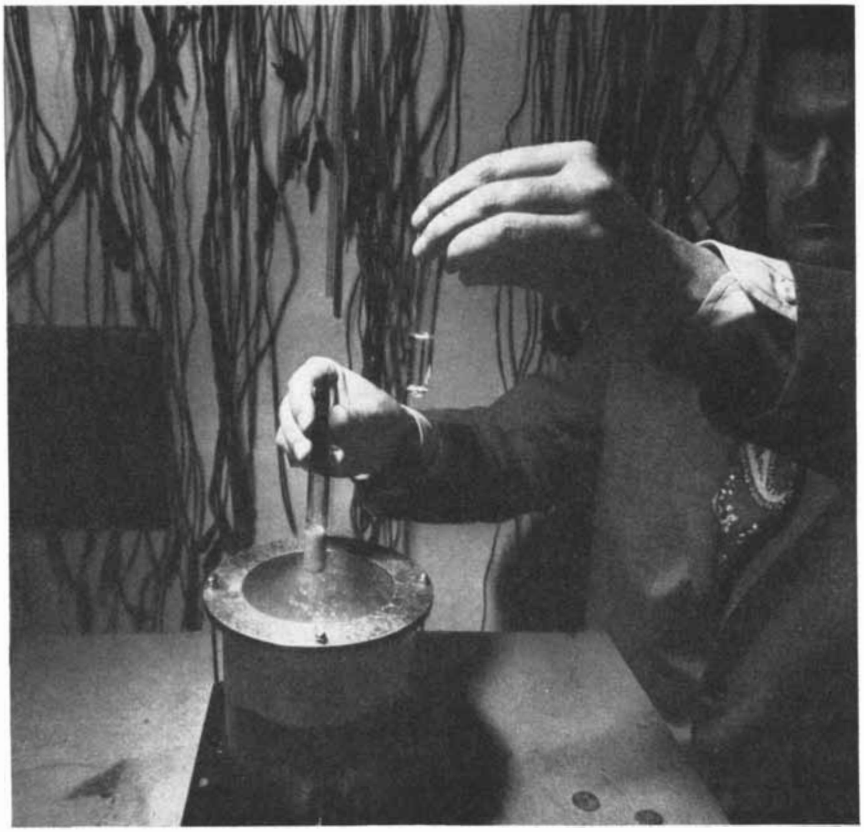
atmosphere might, at first thought, seem mild enough. Actually such a sound would be literally deafening. Ordinary conversational sound produces pressure disturbances too slight even to show up when plotted to scale with a pressure of one atmosphere.

Now let us imagine a sound whose amplitude goes from zero pressure (the nadir of rarefaction) to two atmospheres at maximum compression. The energy content of this superlative sound wave would be close to 1,000 watts per square centimeter of wave front! Practical sirens have never yet reached such intensities. The usual commercial model achieves something like three watts per square centimeter. In the air a sound beam of this power usually has little effect on a solid body; almost all of the energy is reflected. Delicate living tissues or a fluffy or finely shredded material, such as absorbent cotton or steel wool, may absorb the sound and heat up rapidly, but a good part of the heating takes place in the air spaces rather than within the fibers themselves.

Ultrasonics in Liquids

Quite different conditions prevail when we deal with sound waves in liquids. Sound is transferred between a liquid and a solid much more readily than between a gas and a solid or even between a gas and a liquid. In general the ease of transfer depends on the difference in specific acoustic resistance between the two materials; the greater the difference, the more reflection. Acoustic resistance depends largely on density; it is, in fact, the density of the material times the velocity of sound through it. Water has more than 3,000 times the acoustic resistance of air under ordinary conditions, while a typical solid has only 20 times the acoustic resistance of water. It follows that crystals and other solid sound sources, though ineffective in air, do a reasonably good job in water.

The favorite transducers at the present time are three: magnetostriction vibrators (at frequencies below 50,000 c.p.s.), x-cut quartz crystals (at frequencies between 250,000 and one million c.p.s.) and polarized polycrystalline ceramics, notably barium titanate (at all frequencies). All these are solid bodies which change their dimensions under the influence of electricity. The magnetostriction transducer in its simplest form is merely a bar magnet made of nickel, wound with a few turns of wire. When electric current flows through the wire, the bar is magnetized and becomes shorter. When current ceases to flow, the bar becomes longer again. If the current through the coil is varied at the right frequency, the bar can be made to oscillate regularly over a desired range of lengths. The proper frequency for the production of this effect is of course the resonant frequency of the bar, as determined by its length. Not only the magnetostriction transducers but also the crystals and ceramics are nearly always operated at resonance. The electrical excitation must conform to the natural frequency at which the given chunk of material stretches and shrinks, for only in this way can a high output be achieved with a driver of economical proportions.



MERCURY IS EMULSIFIED when held in the sound field of an ultrasonic generator. The test tube at right holds water with mercury at the bottom; the tube at left, the emulsion.

Each kind of transducer has its own advantages and disadvantages. All three kinds have been utilized to good purpose in power-processing devices. A typical quartz-crystal generator is shown in the diagram on page 58. Except that its crystal is driven hard at resonance and there is no reflector (in this case), it operates much like the interferometer. Sound is reflected back to the crystal from the top surface of the liquid, but at high intensity and high frequency the liquid is in extreme and irregular agitation and the surface rises and falls according to no particular pattern. The force of sound radiation forms a miniature fountain: droplets shoot out to different heights, some leaving a trail of fog behind them. Soon the entire display is hidden in a dense fog filling the upper part of the chamber. The fog spills over the walls and finally dispels itself in the surrounding atmosphere.

Is the water boiling? The answer is yes, but when we turn off the sound and dip in a hesitant finger, we are at once relieved and disappointed—the water is only lukewarm. Vacuum boiling has been taking place, but not, of course, in steady fashion, as in the familiar freshman physics demonstration of water bubbling cheerfully in a beaker on a slab of ice, all covered by a bell jar connected to a suction pump. Before us we have, on the contrary, a liquid in which high pressures and low pressures coexist simultaneously in alternate layers, each perhaps a millimeter thick. These layers move up through the liquid with the speed of sound, and the crystal sends out a million new wafers per second. The high-pressure and low-pressure layers are well defined as they leave the crystal, but they become confused as they bounce back downward from the chaotic free surface of the liquid. This greatly complicates the pattern; high- and low-pressure regions, always rapidly changing, are mixed up unceremoniously. Wherever there fleetingly exists a region of lower pressure than the vapor pressure corresponding to the temperature of the liquid, vapor should form. This vapor, however, will immediately saturate the air above the liquid, and additional vapor can only be recondensed as fog above the surface.

The Source of Power

But the story does not end here. Fogs can be produced by other means, and ultrasonics has rather more than this to offer. Let us, for a moment, concentrate on what happens right above the quartz disk during the negative half of the cycle —when the crystal shrinks and pulls its upper face down away from the water. Of course the pressure starts to fall in the layer of liquid immediately adjacent to the crystal surface. We have said that boiling should occur when the pressure falls to the vapor pressure value determined by the liquid temperature. This statement must be re-examined. Vapor will tend to form, it is true; whether it actually does form is another question. Vapor bubbles need to have some kind of nucleus to start from, and under the conditions of our experiment there may be a scarcity of suitable nuclei. When we begin with fresh water in the sound chamber, such nuclei are available in abundance; the water contains dissolved air. But this dissolved air is rapidly driven off in the sound field, leaving a liquid wherein vapor cannot easily form, even though temperature and pressure conditions argue that it should. So, as the pressure drops below the vapor pressure value, vapor still does not form, with the consequence that there is nothing to prevent a further pressure drop in the layer as the quartz crystal continues to shrink away. The pressure falls to zero and then continues to fall through a range of many atmospheres of negative pressure. In a word, the liquid is stretched.

This concept of hydrostatic tensile stress—novel as it seems in view of our everyday observation that liquids can't be stretched—is abundantly documented by theory and experiment ["The Rise of Water in Plants," by Victor A. Greulach; Scientific American, October, 1952]. Indeed, it is only by virtue of this phenomenon that high intensities are possible in a liquid. If our alternating pressure wave were strictly limited, in liquids as in air, to the band of pressures from zero up to two or three atmospheres absolute, then the maximum intensity we could ever reach would be about a third of a watt per square centimeter. In reality intensities a hundred times as

HIGH-INTENSITY WHISTLE is the rod-shaped object in the middle of this photograph. The sound produced by the whistle is focused by the concave reflector on the glass slab at top. Bits of paper placed in the beam are suspended at intervals of half a wavelength.

great are achieved without undue difficulty.

Thus it is possible to set up pressure fluctuations of considerable magnitude. It is easy to see why living tissues subjected to such stresses should be quickly destroyed. But even this does not get quite to the end of the matter. We have to concede that our large negative pressures may become so great that the tensile strength of the liquid is no longer sufficient to maintain perfect continuity throughout the negative pressure region. The liquid is then torn apart; bubbles of empty space come into being. Now vapor can form; it starts to do so with extraordinary rapidity. But then the positive pressure phase returns, and the cavities collapse violently. All this outrageous activity recurs over and over, at the frequency determined by the motion of the crystal. Small wonder that fine-grain dispersions are made, or that chemical reactions are hastened!

The process just described is an extreme and special example of the general phenomenon known as cavitation. The forces involved are apt to elude direct calculation. But even a straightforward reckoning of particle accelerations, based on nothing more abstruse than the known particle velocity and frequency, yields values above 100,000 gravities. This has nothing to do with cavitation; yet it may serve to give an idea of the order of magnitude of the forces brought into play by high-intensity sound in liquids.

Power as a Tool

Knowledge of these forces has been increasing steadily since the great day, a little more than 25 years ago, when R. W. Wood and A. L. Loomis made the first startling disclosure of power ultrasonics in liquids in their laboratory at Tuxedo Park, N. Y. Immediate interest was stirred by their demonstration of a mercury-in-water emulsion; industry was quick to sense that a new tool was at hand to perform unusual feats of mixing. Much attention was given to the possibility of blending paints, of improving the characteristics of liquid fuels, perfumes or photographic emulsions. Yet these possibilities have failed to attain wide commercial importance. Even today we can cite no outstanding example of mass production by under-liquid ultrasonics in the chemical industry.

There has been a very notable success, however, outside the chemical industry. Ultrasonic cleaning now promises to revolutionize the technology for removing oil, dirt, grease and chips from metal parts. The revolution, in fact, has already begun. Items as diverse as ball bearings, vacuum-tube elements, spinnerettes, sewing-machine parts, clock motors, pump and valve fittings, and electric-shaver heads are now being washed cleaner than ever before, and at lower cost and in much less time, by the simple process of dipping them into an appropriate solvent while agitating the solvent at quartz-crystal frequency. In a work piece of irregular shape, the cracks and crevices which are inaccessible by all the usual methods come out clean when treated by ultrasonics.

Ultrasonic cleaning seems utterly simple to a casual onlooker, who never fails to be amazed at the startling transformation wrought in the surface appearance of a greasy strip of metal, inserted for a moment in the sound field. But a physicist knows how deceptive this apparent simplicity can be; in attempting to explain the why of ultrasonic cleaning he goes into the far ramifications of acoustics and thermodynamics, and still is not sure that he knows much of what is happening.

Looking into the future, we can reasonably count on a considerable further development of sonar, of flaw-detection, of ultrasonic cleaning. Lines of advance in other directions are much less predictable; yet the possibilities are numerous and fascinating. We need only mention vibration drilling, vibration bonding of metals, ultrasonoscopy, viscosity measurement for process control—the list can run to great lengths.

In medicine the role of ultrasonics remains to be determined. Much research has been done, some premature enthusiasm has been generated, hopes have been dashed; still the ground has only been scratched. A similarly inconclusive state of affairs appears to prevail throughout the field of biology. Clearly much must be done in the next few decades if only to prove out on the leads already discovered. About possible new leads we hardly dare guess.

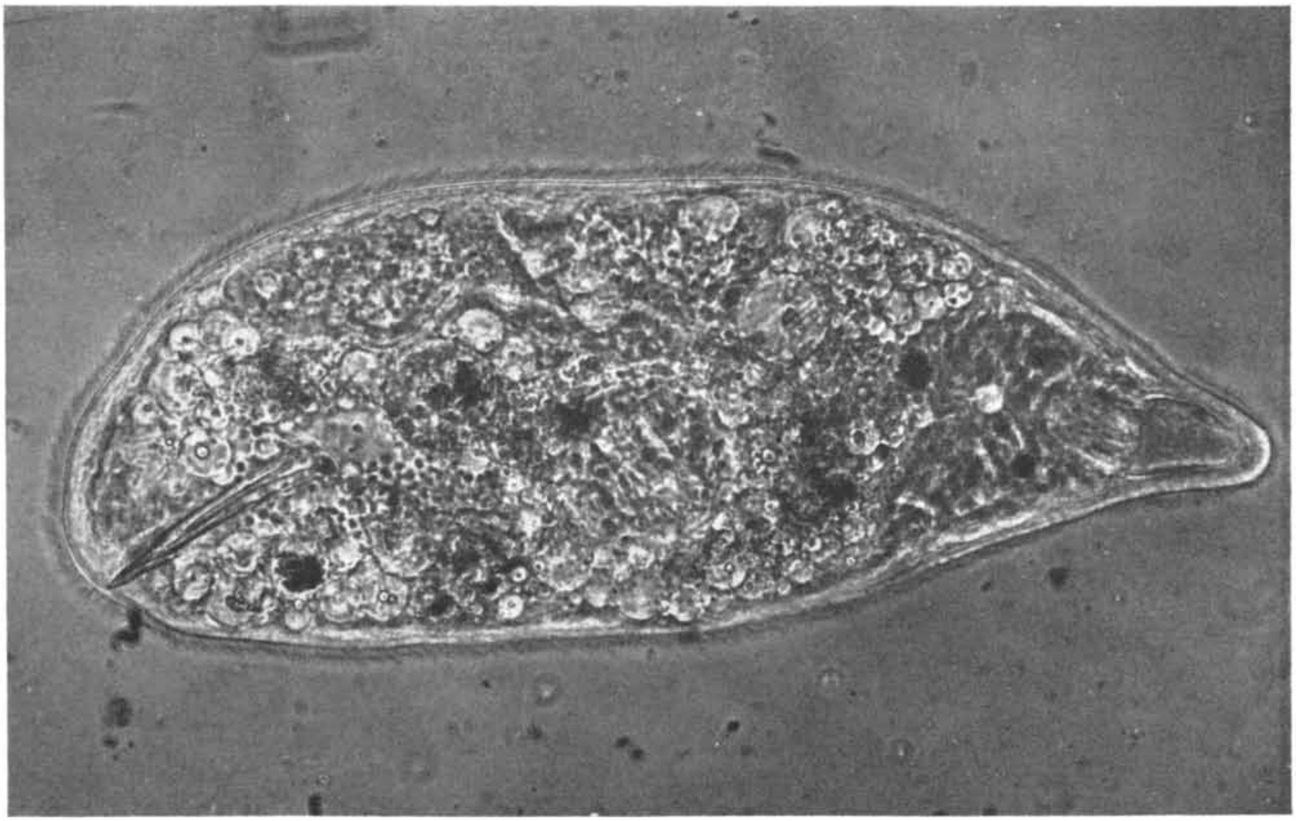
THE LIFE OF AN ESTUARY

In the mouth of a river dwells a rich assortment of creatures from protozoans to fishes. Their environment is perilous, but some clever biological mechanisms enable them to flourish

by Robert M. Ingle

Around the mouths of rivers, where the fresh waters of the land meet the salt waters of the sea, live some of the world's densest populations. This food-rich borderland harbors immense numbers and varieties of living creatures—protozoans, worms, snails, shrimp, clams, oysters and on up through the vertebrate fishes. Life in an estuary may be rich, but it is also almost inconceivably dangerous. The temperature of its shallow waters runs the scale from freezing to over 100 degrees Fahrenheit. Twice each day the ebb and flow of the tides drastically alter the conditions of life, sometimes stranding whole populations to die a high-and-dry or freezing death. Winds, floods and tidal currents often bury the stationary bottom animals under suffocating slides of sand or silt. But the greatest hazard of all is alien water—water that is too fresh or too salty. Aquatic animals are sensitive to the salt content of their watery environment. A sudden rain-fed flood of fresh water from a river mouth can be catastrophic to populations dwelling in the estuary.

In short, the inhabitants of an estuary live in a constant state of insecurity. If these organisms could worry, they would all be psychoneurotics. But from the point of view of an evolutionist, a river mouth is an enchanting place. Life on this planet began in the sea. The estuaries are a threshold across which animals passed from the sea to continental



FLATWORM *Gyratrix* lives in fresh, brackish or salt water. This fresh-water specimen has a system of "flame cells," not quite large enough to be seen in this photomicrograph, which are capable of excreting water that has passed through its membrane by osmosis.

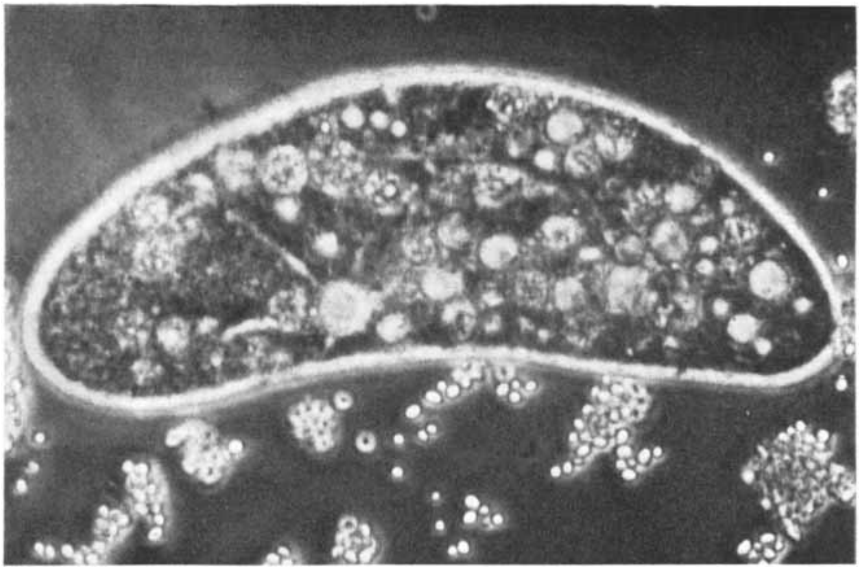
waters, and thence to the land. They are still crossroads of evolution—from a marine to a fresh-water existence and *vice versa*. Like the sonic barrier in the air, a river mouth is an osmotic barrier which can be crossed only by changes in design. And we can see in the estuarine borderland all shades of structural and physiological adjustment to water of varying salinity, including versatile forms that can live indifferently in salty, brackish or fresh water.

By the familiar process of osmosis, animals lose water through their semipermeable membranes when the salt content of the surrounding medium is raised, and they gain water when the outside salinity drops. In other words, water moves toward the higher salt concentration. A close study of the various devices by which estuarine animals cope with this problem has provided an insight into some fundamental biological processes. For almost all animals that have successfully invaded estuaries have some mechanism for maintaining what Claude Bernard, the famous French physiologist, so aptly called "a stable internal environment."

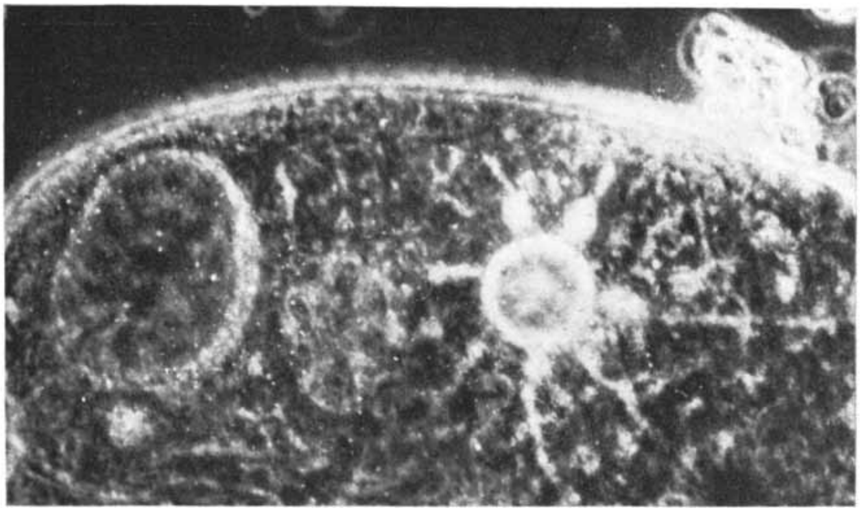
There are at least four ways by which an organism may maintain a stable internal salt concentration when water might invade it from a less salty medium outside: (1) by increasing its internal hydrostatic pressure, through some means such as strong contractions of the body wall; (2) by secreting the water as fast as it enters, through enlarged kidneys; (3) by taking up salts or (4) by developing an impermeable skin.

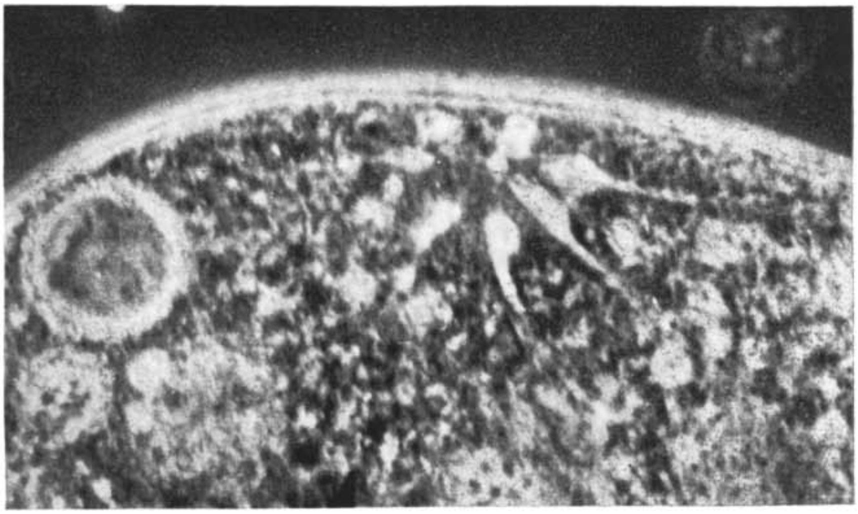
The simple, one-celled protozoan often has a fairly complicated system of avoiding osmotic trouble. Some varieties, when placed in water of less salt than they are accustomed to, collect the incoming water in their tiny contractile vacuoles and disgorge the water through a small pore when the vacuoles are full. The energy for this action apparently is supplied by the respiratory system. If cyanide is put in the water with certain fresh-water protozoans, their contractile vacuoles cease to pulsate. Water begins to accumulate within the animal and it swells. In slightly salty water, however, little or no swelling occurs even when they are treated with cyanide to paralyze their vacuoles. Protozoans similarly seem to have no great need to pump water when the water has a high content of calcium ions; it is thought that the calcium reduces the permeability of their cell walls.

Some flatworms have a so-called

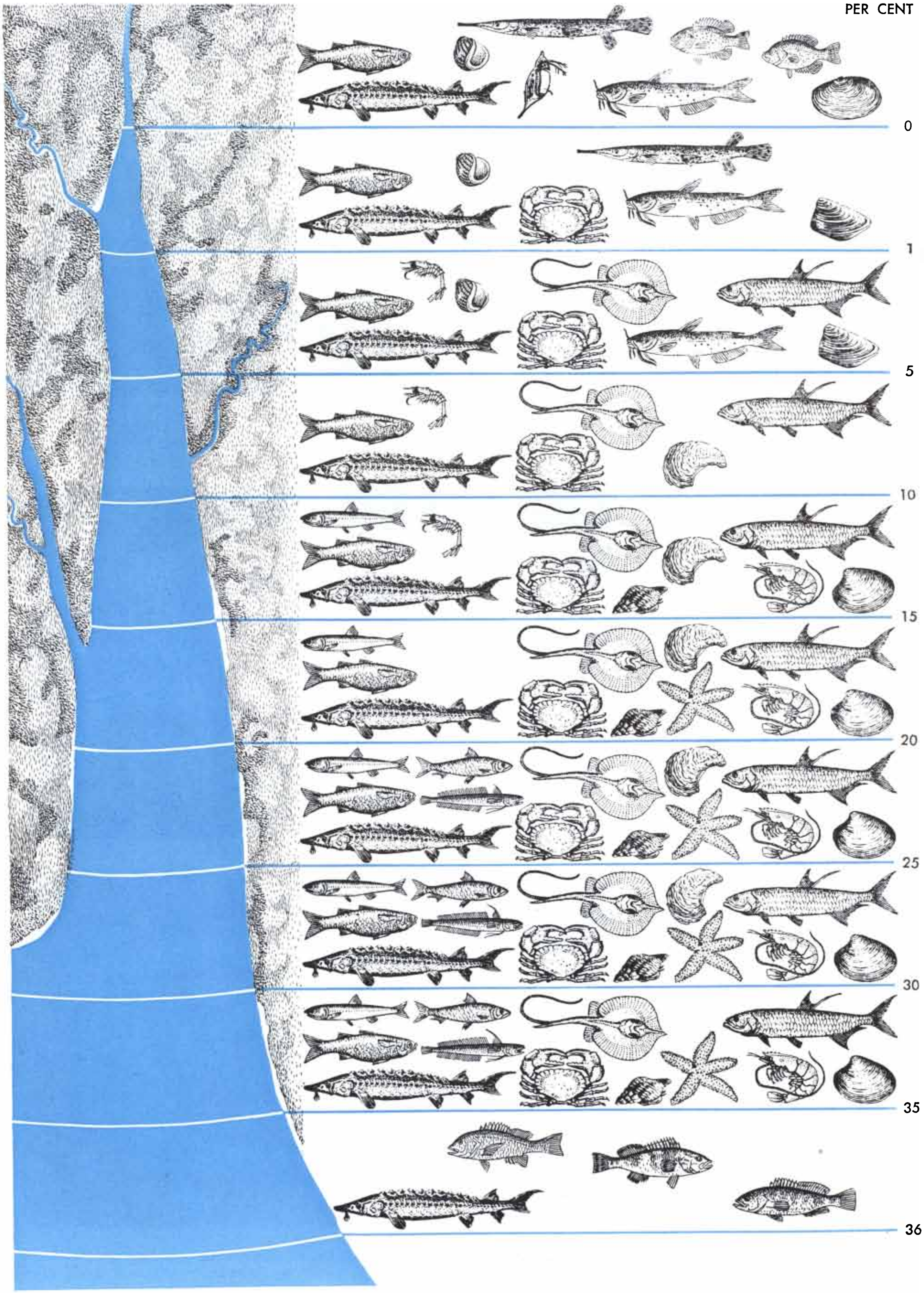


PARAMECIUM is a one-celled animal possessing a simple but efficient organ for the collection and expulsion of water. It is the star-shaped vacuole that may be seen at left center.





VACUOLE of the paramecium is shown in larger scale by these photomicrographs. At top the vacuole is distended with water. At bottom the vacuole contracts and expels water.



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"flame cell" which rhythmically collects and expels water. Fresh-water members generally possess a well-developed flame-cell system; those that live in brackish water have a smaller one, and sea-water specimens apparently have none at all. Another flatworm allows the salt of its protoplasm to seep through its body surface. This has the effect of slowing down the ingress of water. As in the case of protozoans, flatworms seem to have less trouble with lowered salinities if calcium ions are present in the water in fair amount.

Mollusks, which include clams and oysters, have varied methods of coping with the osmotic problem. *Mytilus edulis*, a commercial clam of the British Isles, lowers its own osmotic pressure when that of the surrounding water is lowered; it also seems to excrete some of the entering fresh water. During times of rapidly changing salinity of the surrounding water, some bivalves—particularly oysters—close their solid shell more or less completely and may keep it closed for a time.

Shipworms, which are not actually worms but bivalve mollusks distantly related to clams, have an ingenious mechanism. *Teredo*, a well-known shipworm that bores into wood structures under the water line, likes a high salinity. As it bores into the timber, it keeps the end of its "tail" sticking out of the opening through which it entered—as a sentry, so to speak. The "tail" bears a hard structure called a pallet which can act as a plug. If a sudden influx of fresh water washes over the timber, Teredo quickly pulls its pallet into the hole and seals off its burrow. It can stay holed up for a considerable time.

Crustaceans, such as shrimp, crabs and lobsters, keep out water and salts with their hard "skin." When they molt, their new covering for a time is soft and not so impermeable, but it soon hardens. Biologists have given much attention to a crab called *Carcinus maenas*, which can maintain a relatively high internal osmotic pressure in spite of a substantial drop in the salt content of the surrounding water. Apparently it can take in salts from the water through certain specialized cells of the gills. This means work, and the creature must increase its metabolism to supply the energy.

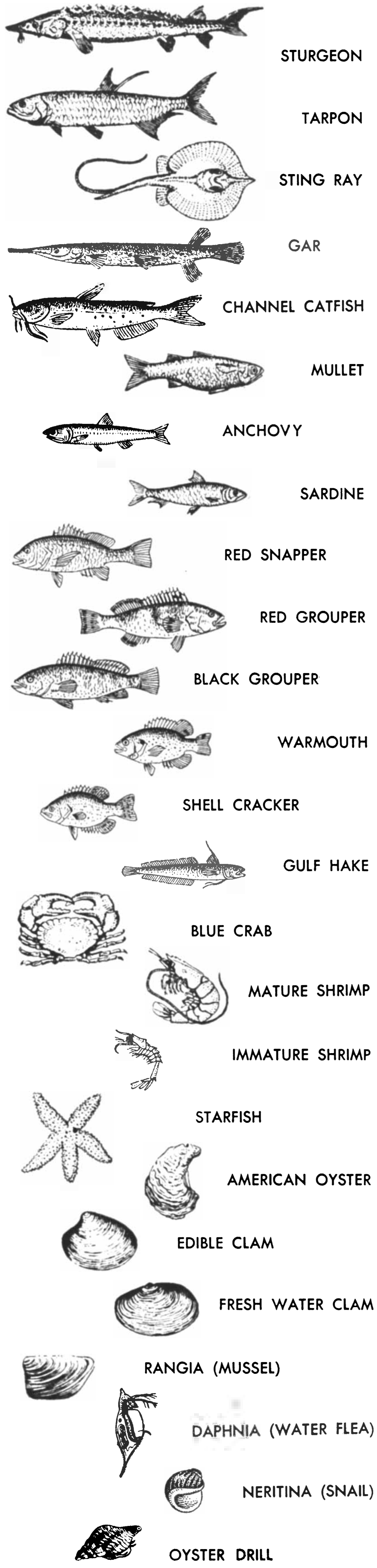
Shrimp thrive under great variations in salinity. They are, of course, an outstanding example of the animals that like to live in the brackish waters of an estuary. A group of biologists of the Marine Laboratory of the University of Miami have for several years carried out studies in the Apalachicola Bay area, one of the Gulf coast's famous river mouths and long a rich growing region for shrimp. We found shrimp (and oysters, crabs and certain fish) living in fluctuations of salinity that seem almost unbearable.

Echinoderms (starfishes, sea urchins, sand dollars and so forth) apparently lack devices to preserve their internal osmotic pressure. As a result, they seldom invade brackish waters that have a low salt content.

It was the ancestors of the fishes, the aquatic animals with backbones, that made the major crossings over the osmotic barrier. The break-through must have been very gradual. Imagine an immense bay, several thousand miles in area. At first this bay is connected with the sea and has a relatively high salt content. Then, as a result of some geologic process, the openings of the bay gradually close up. In the course of perhaps thousands of years the salinity conditions change. The animals, however, are unable to leave. Many die out. But some change gradually and adapt to the fresher water. Eventually their evolving descendants complete the crossing to fresh-water streams. This hypothetical evolution is one of the ways in which the precursors of fishes could have made the transition to fresh water.

Curiously enough, the bony fishes (as distinguished from the elasmobranchs—with cartilaginous skeletons—such as sharks, rays and skates) probably originated in fresh water. If we accept this theory, then it becomes apparent that still another crossing of the barrier must have taken place when the bony fishes invaded the sea. Later some bony fishes crossed the barrier again to reinvade fresh water.

The story of these transmigrations is told in the animals' kidney structures [see "The Kidney," by Homer W. Smith; SCIENTIFIC AMERICAN, January, 1953]. Fresh-water fishes, which have a problem of getting rid of the water that invades their tissues, ordinarily have well-developed kidneys. Many marine bony fishes, having no pressing problems of



ESTUARY AND ITS INHABITANTS are represented in this drawing of a typical river mouth of the northern Gulf of Mexico. The key at right names the various creatures that are shown at left aligned with the zones of salinity in which they are characteristically found. The per cent of salinity is indicated by the numbers corresponding to the schematic lines of division, starting with the fresh water in the river (*top*) down to the open sea.

water elimination, have degenerate renal structures. Marine elasmobranchs have evolved a singular method of keeping their osmotic pressure nearly equal to, or slightly greater than, the surrounding salt water. They maintain the balance by holding a high content of urea instead of salt. Those elasmobranchs that have invaded fresh water have lost much of their urea retention but still retain a concentration about 30 times that of bony fishes—a vestige of their marine origin.

Fresh-water bony fishes have relatively simple methods of osmotic regulation. The skin is fairly impermeable, but the gills and mouth take in substantial amounts of water. The kidneys remove this water from the blood, secreting a dilute urine. When fresh-water bony fishes invaded salt water, they apparently made another adaptation. Since the osmotic pressure of their blood was considerably less than that of the sea water, they were obliged to replace osmotically lost water. This they did in many cases by swallowing quantities of sea water and actively secreting through the gills the salts involved. The apparent impunity with which certain fish such as eels, salmon and mullet spend part of their time in fresh-water streams and part in brackish or salt water is probably the result of the interaction and synchronization of these two opposing devices.

The number of fish that can wander at will among salt, brackish and fresh waters is surprisingly large. Gordon Gunter of the Texas Institute of Marine Science has listed 173 species of such adjustable fish in North America. Some fresh water appears to contain factors which help sea fish to accommodate to reduced salinity. A famous example is a stream in West Florida called Homosassa Springs, which has many salt-water fish. The secret of Homosassa Springs is still unknown, but calcium ions may play a part.

As might be expected, it seems to be easier to cross the barrier from the sea to fresh water than in the other direction. Gunter found that only 2 per cent of the brackish-water fish originated in fresh water. Another researcher, working in two estuaries in the British Isles, found that only two out of 176 species of animals were fresh-water species. All the others had come from salt or brackish water. As early as 1896 a German biologist named Brandt discovered that marine animals in the Kaiser Wilhelm Canal were able to live in brackish water.

All in all, the extremes of living conditions that the denizens of river deltas must endure are literally staggering. As cold-blooded or bloodless creatures, they are at the mercy of the heat and cold of their environment. The temperature of the water may change by many degrees in a few hours. An unusually low spring tide combined with an off-shore wind may leave stationary animals exposed to the air and the rigors of subfreezing temperatures or a dehydrating heat of over 100 degrees. A rain may drench them with almost pure fresh water. Sudden cold waves in winter regularly kill millions of fish and shrimp along the Gulf coast; fishermen walk out on the exposed flats and pick up tons of dead and dying fish, but more are lost than are harvested. In 1941 Gunter discovered that most of the fish and shrimp along the Texas coast migrate, like birds, away from the cold Texas winters.

Gunter has recently confirmed, by an analysis of old records, that the mouth of the mighty Mississippi is undergoing changes which doubtless will greatly affect the animal life of that estuary. A delta stream called the Atchafalaya, which used to be small, has taken over some of the drainage formerly carried by the main mouth of the river. Man and his levees have contributed to the change, and it is expected that the trend toward the Atchafalaya will continue. Probably some of the mobile animals in the delta are slowly migrating to new locations and some of the stationary forms are declining.

Long-term geological changes also must be modifying life in the estuaries. For instance, the waters of the Atlantic seaboard and the Gulf of Mexico are apparently rising with respect to the land, either because of the melting of polar icecaps or a possible sinking of the edges of the continent. H. A. Marmer of the U. S. Coast and Geodetic Survey has published some startling findings: at several locations along the Atlantic and Gulf coasts the sea level has risen several inches in the past 25 years.

In a world concerned about its future food supply, the estuaries are a matter of great practical importance. They are the nurseries for many edible and succulent animals—indeed, one of the chief sources of our planet's wealth. In 1948 the Gulf of Mexico harvest of shrimp alone was nearly 118 million pounds, worth almost $25 million. Crabs, clams, oysters, scallops and estuarine fish support other great globe-wide fishing industries. When man learns more about the nature and management of the fabulously rich and turbulent estuaries, he will benefit enormously—nutritionally and monetarily.

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The Language of Homer's Heroes

In 1952 an English architect deciphered the script called Linear B, providing a new key to the study of the people who lived in Greece 800 years before its classical period

by Jotham Johnson

In archaeology 1952 will go down in history as the year when the Mycenaean script was deciphered. It would be hard to imagine a more romantic or more hungrily sought ancient writing than this. It records the language of the Greeks of whom Homer sang—the Greeks of the time of the Trojan War, the adventures of Odysseus, the Argonauts and the Twelve Labors of Heracles. To these Bronze Age Greeks of 1600 to 1100 B.C., whom Homer called the Achaeans, scholars have looked for the seeds of culture that yielded the great flowering of classical Greece 800 years later. They have mined the pages of Homer, prowled among the ruins of Mycenae and Tiryns, pieced together the pathetic fragments of the Achaeans' wall-paintings, carvings in ivory, broken pottery and household gods, even unearthed the prehistoric citadels of Troy and Mycenae, proving once and for all that Homer was not a fiction writer. But of writing from that period there was until just yesterday hardly a trace. The Achaeans left so little in the way of

CLAY TABLET inscription with Linear B characters was found in the remains of a palace at Pylos on the west coast of Greece by the University of Cincinnati archaeologist Carl W. Blegen. The table dates back to the closing years of the 13th century B. C.

written records that no one really knew whether their language was Greek.

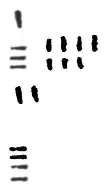
For a long time it was believed that the Achaean princes who ruled Greece and brought Troy to her knees were illiterate. Homer speaks only once of writing; he tells of King Proetus of Argos giving Bellerophon a written message to take to the king of Lycia. The message asked the king to kill Bellerophon. Bellerophon delivered it; maybe he was illiterate, maybe as a man of honor he did not break the seal. Homer himself, whether or not he was blind, almost certainly did not know how to read or write; his *Iliad* and *Odyssey* were passed on by word of mouth and written later.

The story of the Mycenaean script begins 50 years ago when an English archaeologist, Arthur Evans, dug into the great palace of King Minos, the famous Labyrinth, at Knossos on the island of Crete. The site of Knossos had never been forgotten; in fact, Heinrich Schliemann, the German archaeologist who dug up Troy, had tried to buy the palace site to dig it but turned away in disgust at the high asking price. Evans, less easily exasperated, saw the deal through, and in March, 1900, began his excavations at the Palace of Minos.

Among the myriad of things he found were 1,900 clay tablets, inscribed in strange new symbols which no one could read. Evans devoted many years to the attempt to break the code, but he died with the secret still hidden from him.

The tablets were written in two scripts, which Evans named Linear Script A and Linear Script B. He decided that certain columns of symbols which he found on some of the Linear B tablets must be the names of articles; sometimes there was a rude sketch of the article—a chariot frame, a wheel, spears, arrows, swords, metal ingots—beside the name. Next to it also were obvious number symbols. Evidently these tablets were the royal stewards' accounts of military stores.

It was no great problem to decipher the numbers. When you find on a tablet the set of symbols shown below,



it is easy to see that this is a problem in simple addition, with the vertical strokes representing single units and the horizontal ones 10s; that is to say, 1+37+2=40.

But the word symbols were another matter. If the sounds represented by these symbols could be recovered, the words might be pronounced; if the words could be pronounced, the keen ear of a trained linguist might detect resemblances to related words in a known language (cognates, we call them); once cognates were found, the breaking of the code would follow as the day the night. But until 1952 no one was able to decipher those symbols, even with the help of the little pictures.

Since the distinct sounds of speech number between 15 and 40, depending on the language (English has 31), the number of possible permutations and combinations is in the billions. In a good alphabet—English does not have a good alphabet—each of the distinct sounds is represented by a separate symbol. But it took several thousand years for primitive man to catch on to this simple idea. The early languages used symbols for single sounds or combinations of sounds. Thus the pictographic script of ancient Egypt, to which we give the special name of hieroglyphics, has more than 400 symbols, and the cuneiform of Babylonia has almost as many. To learn how to read and write these with facility must have taken, quite literally, the best years of a man's life; few except professional scribes bothered with it, and certainly the man in the street was shut out.

There is a kind of writing intermediate in difficulty between the hopelessly complex hieroglyphs and the admirably simple alphabet. Called the syllabary, it has symbols for the simple vowels and other symbols for combinations of consonants with these vowels, forming syllables. When Evans found that Linear B consisted of some 60 or 70 characters, he assumed correctly it was a syllabary.

Now we must look at a syllabary which eventually provided some crucial clues that made it possible to crack the Mycenaean code. This is the script of ancient Cyprus, an island not far from Crete. The Cypriote script has about 55 symbols. Five of them stand for the vowels *a*, *e*, *i*, *o*, *u*; the other 50, for combinations of consonants with them, forming open syllables: *ka ke ki ko ku*, *ra re ri ro ru*, and so on.

It has some awkwardnesses; for instance, it makes no provision for touching consonants. Combinations such as *pro* have to be written *po-ro*; Apollo comes out *a-po-lo-ni* (dative); but Stasicrates is *sa-ta-si-ka-ra-te-se*. When the

CONSONANT	VOWEL 1	VOWEL 2	VOWEL 3	VOWEL 4	VOWEL 5
(H-)	A AI	E	I	O	U
D-	DA	DE	DI	DO	DU
J-	JA	JE		JO	
K- G- CH-	KA	KE KWE?	KI	KO	KU
M-	MA	ME	MI	MO	
N-	NA NWA ?	NE NEKO?	NI	NO	NU
P- B- PH-	PA	PE PTE	PI	PO	PU
QU- GU-		QE	QI?	QO	
R- L-	RA RJA	RE	RI	RO RJO	RU
S-	SA	SE	SI	SO	SU
T- TH-	TA TJA?	TE	TI	TO	TU
W-	WA	WE	WI	WO	
Z-		ZE		ZO	ZU?

PHONETIC VALUES for 68 of the 88 Linear B characters are presented on a syllabic grid. Each combination of consonant and vowel is followed by its supposed Linear B character. The vowels are given in the row at the top; the consonants, in the column at the left.

nasals *m* and *n* precede other consonants, they are omitted. A reader familiar with such conventions would be delayed only briefly. A worse source of confusion, to us at any rate, is the failure of the Cypriote script to distinguish between such related sounds as *t*, *d* and *th*, or *p*, *b* and *ph*. *Pa*, *ba* and *pha*, for example, were all represented by the same syllable; there was no way of distinguishing, in writing, between *Paros* (name of an island), *baros* (burden) and *pharos* (lighthouse). The reader was left to guess from the context.

We shall see presently how the Cypriote syllabary of 400 B.C. helped solve the Linear B script of 1300 B.C. although there was no certain connection between them. Meanwhile the generation between the two world wars attacked Linear B from many other angles. Bronze Age pottery with short inscriptions scratched or painted in Linear B symbols began to turn up in excavations in various parts of the Greek mainland. Those who assumed that Linear B was the exclusive property of King Minos' subjects, the Minoans, saw Minoan conquerors behind every Greek bush; others argued that the Linear B script might well have been used to write the Greek language. Pots inscribed in Linear B characters came to light in Asia Minor, Cyprus, Syria and Palestine. A Bronze Age storage-jar lid with two Linear B symbols was found in Cyprus; John F. Daniel of the University of Pennsylvania proposed to read them as *ku-the*, which in Greek would mean "put the lid on."

A Brooklyn College linguist, the late Alice E. Kober, did valuable spadework. She found that sometimes a word had several different endings (final characters). She thus made the important discovery that the language of the Linear B tablets was inflected in the manner of Greek or Latin. There are those who think that Miss Kober, if she had lived, would have been the first to tear apart the veil.

In the meantime a fuse had been lit which was to blow the whole business apart. In 1939, a few weeks before World War II got under way, the University of Cincinnati archaeologist Carl W. Blegen began excavating a Bronze Age palace at Pylos on the Greek mainland. Nestor, the long-winded orator of the *Iliad* and the *Odyssey*, lived at Pylos, and Blegen thought it might be his palace. Among his first finds were 600 clay tablets, similar to those of Knossos and inscribed in a script which was immediately recognized as Linear B.

To some scholars, this only confirmed what they had believed all along: that the Achaeans were not Greeks at all, but some sort of feudal government imposed from without, no doubt by the Minoans. If the tablets were in the Minoan language, the solution of the script would be as far off as ever. But there was the exciting possibility that the Pylos tablets might actually be in the Greek language, written in Minoan characters.

The war delayed publication of these tablets. They were finally published in 1951 by Emmett L. Bennett, Jr., a young colleague of Blegen's, and in the following year the Linear B tablets from Knossos also were published in full by John Myres, who had assumed the responsibility for them after Sir Arthur Evans' death. This opened the race to contestants in all countries. As it happened, the first across the finish line was Michael Ventris, an Englishman—not an Oxford don but a successful architect with a classical background and a flair for cryptography.

As in Crete, the Pylos tablets were accounts and inventories. Ventris never doubted that they were in Greek. Sketches of men and women suggested the Greek words *patêr* and *mâtêr*. A sketch of a tripod, a three-legged stand for a cauldron, suggested the Greek word *tripodes*. The Linear B word, of four symbols, might be *ti-ri-po-de*.

The Cypriote syllabary furnished useful hints. Ventris assumed that the Minoan script, like the Cyprus one, did not distinguish between long and short vowels, omitted *m* and *n* when they preceded other consonants, and represented consonants related to one another (for example, *pa*, *ba*, *pha*) by the same symbol. He also found that a single set of symbols stood both for *r* combinations (*ra*, *re*, *etc.*) and *l* combinations (*la*, *le*, *etc.*). He was forced to assume that a word ending in a consonant had the final symbol omitted, because no consonant could be represented without a following vowel.

Trying out various sounds for the symbols on these assumptions, and keeping in mind the eccentricities resulting from the ambiguous phonetic system, Ventris presently began to get a whole series of Greek words [*see list on next page*]. He also deciphered some familiar proper names, as follows:

te-se-u	Theseus
e-ko-to	Hector
a-ta-no	Antanor
ka-ra-u-ko	Glaukos
a-ka-ma-jo	Alcmaeon
ka-sa-to	Xanthos
pu-ro	Pylos
pa-i-to	Phaistos
ko-no-so	Knossos
a-mi-ni-so	Amnisos
a-ta-na	Athena
e-ra	Hera
po-se-da-o	Poseidon
e-nu-wa-ri-jo	Enyalios
e-re-u-ti-ja	Eleuthia
di-wo-nu-so	Dionysos

As you can see, a cryptographer's task is not over when the transliteration is completed; there still remains the job of recognizing the Greek word behind it. But the overwhelming proof that Ventris has in fact broken the code is the astronomical odds against coincidence. In one entry occurs a proper name of eight symbols. Substituting predetermined values for these, he obtained *e-te-wo-ke-re-we-i-jo*. This is the familiar Greek name Eteocles. The odds against coincidence in this single example are of the order of 200 billion to one. Anyone who wishes to question Ventris' methods or his results has to move this mountain first.

With the collaboration of John Chadwick, Ventris published a succinct report of his progress in the 1953 volume of *The Journal of Hellenic Studies*. (The title of his article, "Evidence for Greek Dialect in the Mycenaean Archives," is one of the greatest examples of understatement on record.) Later he published a further account in the December, 1953, number of *Antiquity*. At that time he had obtained the phonetic values of 68 of the 88 symbols on the tablets. He had recovered about 200 words from the earliest form of Greek known—at least as old as the 14th century B.C.

When the remaining symbols are identified and the rest of the tablets are read, we shall have a small working vocabulary of the language of Homer's Achaean heroes—Agamemnon, Odysseus, Achilles, Nestor and the rest. All our historical Greek grammars will be obsolete. The Achaean dialect is very different from the Greek of Aristophanes and Plato, and different even from the Greek of Homer's own day. Homer must have lived a long time after the Trojan War.

Ventris found on the Achaean tablets the names of occupations which already have provided the raw material for a sociological study. The list of occupations depicts a highly organized Bronze Age society engaged in agriculture, industry, commerce and defense, with such professional specialists as armorers and bowmakers, goldsmiths and bronzeworkers, stokers, potters, cooks and bakers, harrowers, cowherds, shepherds and goatherds, huntsmen, shipbuilders, oarsmen and longshoremen, tanners, fullers, tailors, doctors, property owners, supervisors, overlords and kings.

The evidence is not closed. Blegen, resuming his work at the Palace of Nestor at Pylos, found fresh deposits of inscribed tablets in 1952 and 1953, and Alan J. B. Wace, British expert on Mycenaean archaeology and an associate of Blegen, has finally made the promising first discovery of Linear B tablets at Mycenae.

An ironic surprise is that the Linear B tablets from Knossos turn out to be in Achaean Greek, not in Minoan. The Achaeans captured the Minoan citadels, and installed their own administration and accounting system, earlier than used to be thought. The Linear B tablets found by Evans therefore can be read, and the wealth of historical, social and linguistic material they conceal can be dug out. A corps of scholars in commu-

	SYLLABARY	GREEK	MEANING
𐀈𐀁𐀫	DO-E-RO	DOULOS	BONDMAN
𐀈𐀁𐀨	DO-E-RA	DOULE	BONDWOMAN
𐀞𐀏𐀙	PA-KA-NA	PHASGANA	SWORDS
𐀀𐀐𐀫	A-KE-RO	ANGELOS	MESSENGER
𐀂𐀋𐀩𐀊	I-JE-RE-JA	HIEREIA	PRIESTESS
𐀙𐀄𐀈𐀗	NA-U-DO-MO	NAUDOMOI	SHIPBUILDERS
𐀀𐀵𐀡𐀦	A-TO-PO-QO	ARTOKOPOI	BAKERS
𐀨𐀠𐀴𐁁	RA-PI-TI-RAI	RAPTEIRAI	SEMPSTRESSES
𐀂𐀊𐀳	I-JA-TE	IATER	PHYSICIAN
𐀶𐀏𐀳𐀩	TU-KA-TE-RE	THUGATERES	DAUGHTERS
𐀡𐀕	PO-ME	POIMEN	SHEPHERD
𐀵𐀰	TO-SO	TOSSOS	SO MANY
𐀒𐀺	KO-WO	KOUROI	BOYS
𐀁𐀒𐀳	E-KO-TE	EKHONTES	HAVING

LINEAR B WORDS are compared with Greek after transliteration into our alphabet. Linear B is a syllabary rather than an alphabet; its characters represent syllables rather than letters.

MINOAN WORDS IN ENGLISH

Some of the words of the still mysterious language of the Minoans made their way into Greek, and from Greek to Latin, and so to English. Among English words known to be derived from Minoan are:

Words ending in -inth

absinthe	labyrinth
acanthus	mint
currant (from Corinth)	plinth
	terebinth
Cynthia	turpentine (terebinthine)
hyacinth	

Words ending in -ss

abyss	cypress
byssus	narcissus
colossus	Parnassos

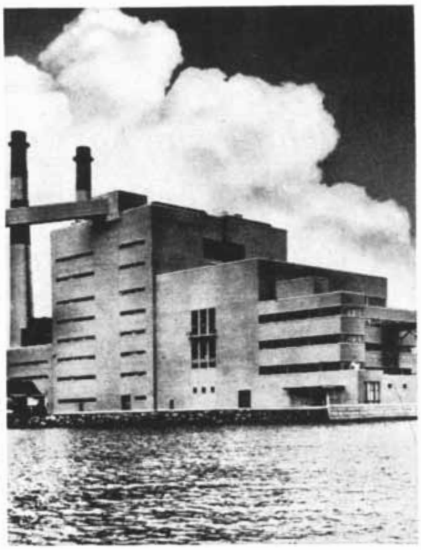
Words which may come from the Minoan:

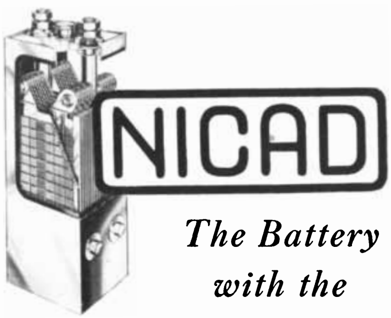
asparagus	hymn
asphodel	paean
daffodil	porphyry
cane	purple
canna	sandal
cannon	sesame
canyon	sponge
dithyramb	wine
govern	

nication with Ventris is working on them now.

As for the Linear A tablets Evans found, it seems certain that they are in a different language. They belong to strata earlier than the Achaean conquest of Crete. These tablets are not only earlier but far less numerous than the Linear B. There is plenty of evidence for a Minoan language not closely related to Greek; perhaps the language of the Linear A tablets is Minoan. Since at least two thirds of the Linear B characters are either identical with Linear A symbols or appear to be developed out of them, the prospects of obtaining phonetic values for Linear A are more than fair. There is hope that the full decipherment of Linear B will be followed by the decipherment of Linear A.

The last walls of mystery around the preclassical civilization of Greece are crumbling, and some of us have derived wry pleasure from the thought that the winning thrust was made by an amateur, not a member of the union at all.





Are Wild Animals in Captivity Really Wild?

Behind the bars of the zoo the lion drowses and the elephant clowns. Let no one be deceived, says the author. Such animals are not domesticated. Turned loose they can become wild again

by H. Hediger

Biologists have often raised the question whether wild animals in captivity can still be considered wild. After all, in a zoo a captured animal is no longer left to its own devices: it is sheltered, well-fed and, most important, is constantly in the company of human beings and sequestered from its enemies in nature. The English zoologist Helen Spurway, in an article called "Can Wild Animals Be Kept in Captivity?", replying to my 1950 book *Wild Animals in Captivity*, argues that it is just as impossible to breed genuine wild animals under artificial conditions as to stand in a bucket and pick oneself up.

Everything of course depends on what one means by a genuine wild animal. It is therefore indispensable to try to define the term. To begin with, wild animals can be contrasted with domestic animals, which owe their origin to man and differ from their wild ancestors in many hereditary characteristics. Assuming that only an animal which has evolved in the free state without interference from man can be called wild, what transformations does it go through when it is transplanted to an artificial environment, let us say a zoo?

First of all, it must lose its tendency to flee from man. Any captured wild animal must become adjusted to the artificial environment, particularly to the continuous presence of people, if it is to feel at ease in captivity. At the very beginning it suffers the trauma of an abrupt change from freedom to extreme confinement—in a trap and the small cage in which it is transported. This initial phase is particularly interesting to us; it magnifies, as it were, certain aspects of captivity. If the severe restraint lasts only a short time, the wild animal obviously will not be much affected by it in the long run. For example, field hares trapped in Hungary and transported to Switzerland to be released there as game animals certainly are still wild in every respect when they are set free. The same is true of beavers, ibexes, chamois and red deer which are shipped from one part of the world to another to found new colonies. Nobody will doubt that they remain genuine wild animals, even though they have to get used to a different seasonal rhythm and to new ecological conditions.

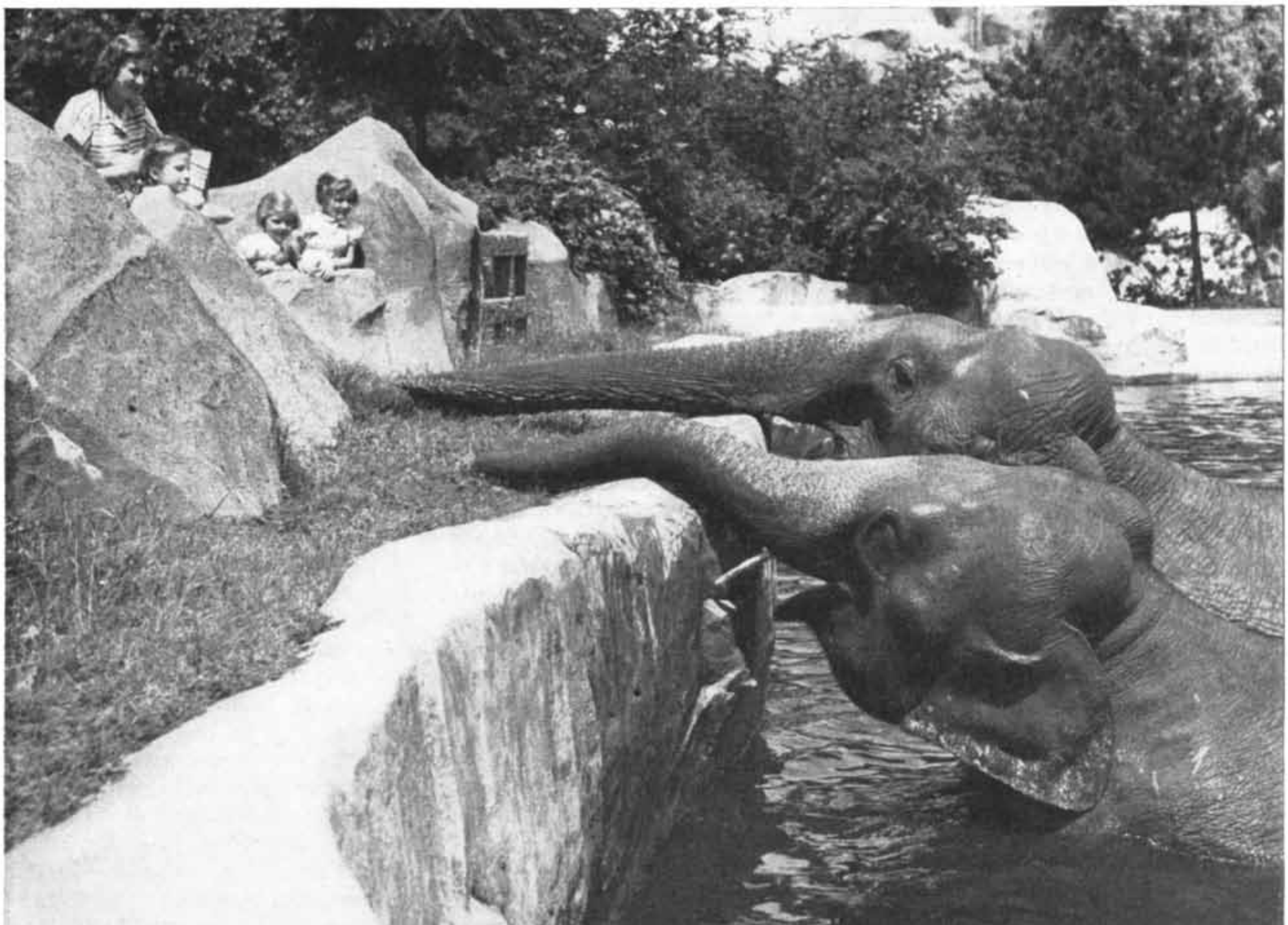
When the transport of a wild animal takes a long time, there may be lasting psychological effects. In 1952 a rhinoceros was shipped from India to Switzerland and during the three months journey was confined in a transport trunk in which it could not turn. The animal arrived in excellent physical condition, but in a very changed psychic state. It had been highly excited when it was maneuvered into the transport cage in Assam; when it emerged in Switzerland, it was entirely tame, without any flight tendency. During the trip the rhinoceros, constantly surrounded by keepers, had ceased to regard man as an enemy.

Does this tameness—the loss of the tendency to flee from man—change the character of a wild animal fundamentally? I believe not. It is certainly not hereditary. The Swiss mountains are inhabited by about 1,000 ibexes which are all descended from animals imported, raised and even born in captivity within the past few decades. Yet the free animals are as shy and as difficult to hunt as chamois. This despite the fact that the ibex is a species which is quickly and strongly affected by captivity. Similarly, field hares that had been kept in small cages for four generations showed as strong a flight tendency as ever when released. They retained all the characteristics of wild animals. It is true that these particular hares had been raised in special circumstances wherein they never saw a human being at a distance of less than four meters; the keepers who fed them and cleaned their cages kept out of sight. Thus the animals had a relatively "wild" environment, though in narrow confinement.

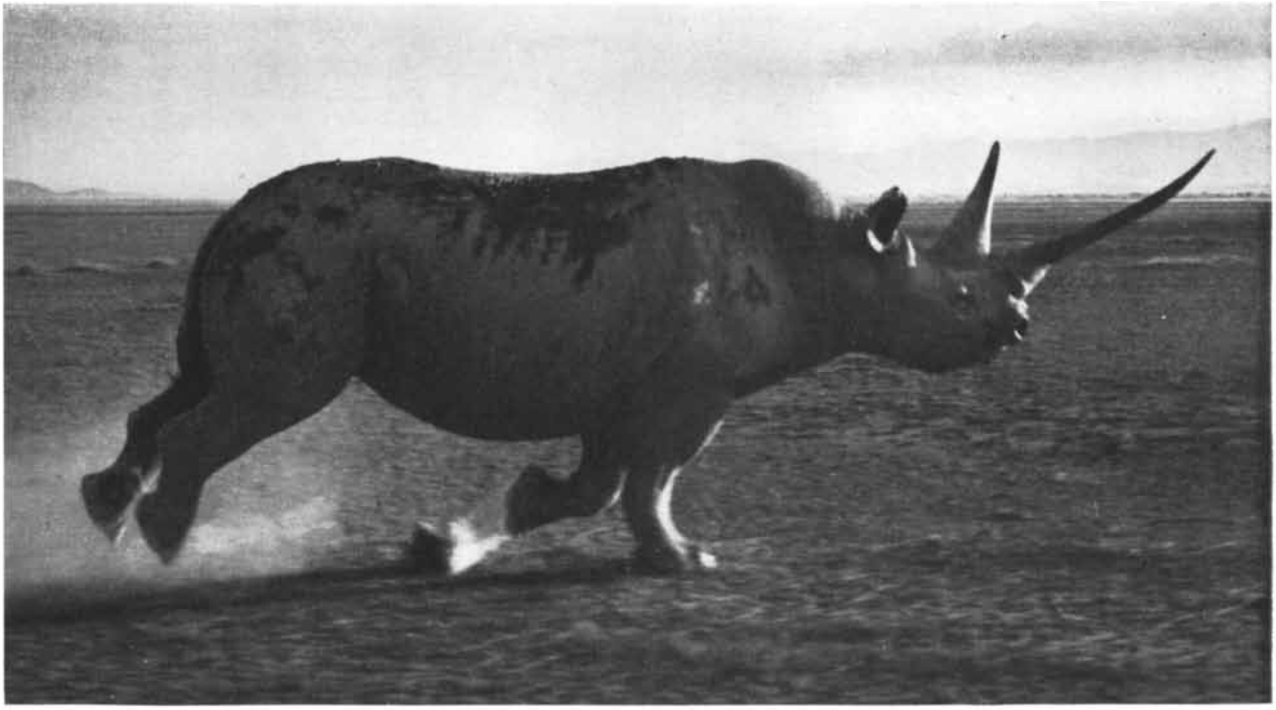
Tameness is a human conception, implying an attitude of trust. Since expressions such as trustfulness, lack of shyness and the like have a strongly anthropomorphic flavor, I prefer to define tameness as that stage in the relationship between animal and man at which the animal no longer shows any flight tendency. We can measure this tendency as flight distance—the distance to which an animal will suffer an enemy to approach. For a tame animal the flight distance is zero; it will let man touch it.

Two qualifications are necessary here. Some animals keep a certain distance even with members of their own species, and they will never allow one of their fellows or a human being to touch them. The second qualification is that tamed animals regress in their relations with man unless the close relationship is continually renewed. In every tame animal there remains a core of wildness which under appropriate circumstances can be reactivated. Even in quite tame circus

WILD ELEPHANTS were photographed by the noted animal photographer Ylla as they fed in a grove of Euphorbia trees in the African colony of Uganda. She found that elephants were extremely difficult to approach and the most dangerous of the African mammals.



TAME ELEPHANTS, bathing in the tank of the great Vincennes zoo near Paris, probe for tidbits from children. These are Indian elephants, more common in captivity than the African species. They are marked by large domed heads and relatively small ears.



WILD RHINOCEROS was photographed by Ylla as it galloped across a dry lake bed in Kenya. It had just charged her speeding station wagon and glanced off. Although rhinoceroses seldom have enough room to make such charges in a zoo, they remain intractable.

animals wildness flares up briefly when they are excited. The trainer as a rule avoids exciting them; when he does want to provoke a short regression to the wild state for show purposes, he uses carefully limited doses of excitement.

Tameness is sometimes confused with domestication, but it is fundamentally different. A tamed wild animal is still a wild animal; its tameness can vanish. The loss of the flight tendency is purely individual—an acquired character which is hardly likely to be hereditary. Partly it is a matter of habituation. For example, in Europe free-living deer have become so used to passing railroad trains that they no longer are disturbed by them; in some regions they hardly lift their heads when the steel monsters whiz past. They still have a tendency to flee from human beings, however. Similarly in Africa big game on reservations—elephants, rhinoceroses, hippopotamuses, giraffes, lions and so on—become accustomed to automobiles and often will let them approach fairly close. Many animals in the zoo, such as monkeys and hoofed creatures, show habituation to the continuous presence of people on the other side of the fence. But these animals are not truly tame: generally they will not allow anybody to touch them, and they tend to exhibit escape reactions when a human being enters the cage.

In the case of really tame animals undoubtedly a learning factor is involved. They have learned that certain human individuals, whom they recognize, will not harm them but on the contrary bring food, friendship and pleasure. Occasionally an animal identifies its keeper as a fellow animal and treats him like a member of its own species—it has a "zoomorphic" attitude toward him. Certain young animals during a sensitive phase of their development may take a human being for their parent animal. But the development of these intimate relationships of course does not change the animals' hereditary endowments in any respect.

It is true that many animals are affected physically by their confinement, even though they may come directly from the wild. (Among those seldom or never born in captivity are elephants, gorillas, cheetahs, okapis, brown hyenas, Malayan bears, rhinoceroses and most of the large birds, *e.g.*, marabous and shoebills.) Because they have not experienced the same strenuous training or been exposed to the same ruthless selection as in nature, some animals reared in captivity become runts; a notable example is the fox, whose reactions in captivity have been extensively investigated. But many others (for instance, polar bears, sea lions, elephants) never are stunted in captivity, as far as is known. Furthermore, runts are not unknown in the wild. It would be desirable for hunters, as well as zoo keepers, to weigh their animals precisely so that we might have more data for comparison.

Nowadays menageries are taking more and more care to develop their young animals physically through good diet, exercise, "activity therapy" and social grouping in large enclosures instead of solitary confinement in narrow cages. Good food in correct doses contributes appreciably to the conservation of the health and normality of the wild animals in the zoo. The "menagerie symptoms" which used to be almost the rule are only rarely encountered now. As a result morphological differences between animals in the wild and their counterparts in a zoo are no longer as conspicuous as they used to be.

There remains the question whether wild animals lose their wildness after they are bred in captivity. Theoretically the longer breeding goes on, the more the progeny may deviate from the original wild parents as a result of mutations. For certain labile species which are easily affected by the captivity milieu (*e.g.*, the fox) a succession of generations in the zoo may be considered as practically the beginning of domestication. We may recall here the famous lions of Leipzig, of which the 1,000th specimen had been bred in captivity at the start of the Second World War. Many of these progeny had deformities; some showed partial albinism, a definitely hereditary trait. But most species of menagerie animals do not exhibit such stigmata, even after extended breeding.

Dr. Spurway points out that mating in the menagerie is not typical of that in nature: already the first generation born in captivity is either too inbred or too outbred. With regard to inbreeding, it is by no means so unnatural as is often believed. All investigators who have studied the sociology of mammals in the wild in recent times have found a considerable amount of inbreeding; for instance, J. Beninde found this in the red deer, C. R. Carpenter in the howler monkey and F. Steiniger in the wild rat. As for extreme outbreeding, that too is by no means foreign to the free state. Single individuals or groups very often are thrown into new environments by natural forces such as storms, droughts, floods or fire, and mate with animals in their new habitats. Where different races border on each other, numerous transition types are found. Moreover, wild populations, particularly of big game, are by no means always so homogeneous as is often assumed. Even within the same herd of elephants, giraffes or buffalo there are occasional variants which defy classification by the taxonomist.

These remarks about the raw material of a breed in the free state and in captivity are only intended to emphasize the fact that the "unnatural" matings in the zoo can be exaggerated. Not everything in the zoo is antinatural. One is daily reminded of this fact by the great numbers of animals that voluntarily invade the zoo to make their clandestine homes there. Among them are not only mice, rats, sparrows and crows but also martens, foxes, skunks, raccoons, coyotes and so forth. Their wild-animal character is in no way diluted by their living in the zoo. Incidentally, it is striking how resistant to taming these very animals are apt to be. Creatures that have a predilection for the seemingly domesticating environment often are most refractory to human control. The classic example is the house sparrow. This bird will force its way into a zoo aviary even through narrow wire netting, but if it is locked in for breeding, it immediately responds with strong reactions and stubborn resistance. Rare indeed are the instances in which house sparrows have reproduced in captivity. On the other hand, the fact that man has not yet succeeded in breeding some animals in captivity does not necessarily mean it is impossible. It may simply mean we do not yet understand them. Certain animals which used to be considered non-breeding (*e.g.*, the Indian elephant, the polar bear, the chimpanzee) are now bred in many zoological gardens.

The zoo is commonly pictured as a domesticating environment in which natural selection has ceased to operate. Yet breeders have it in their power to eliminate recognizable deviations from the wild type and so retain most of the characteristics of the original wild animal. For that matter, is the wild animal in nature still the same creature as it was before man came on the scene? Has not civilization restricted the migrations of free animals and forced adaptations upon them? The stork, the swallow, the house mouse and other animals that make use of human structures, the Australian kangaroos driven away by domestic sheep, the New Caledonian kagus threatened by imported dogs and pigs, the managed seals of the Antarctic, the hunted whales of remote oceans—all these have had their lives changed, directly or indirectly, by man. The bison in America and in Europe, the blesbok antelope and the white-tailed gnu in South Africa live only in enclosures and reservations of human making.

So "original" or "natural" today is but a relative term. This even holds for invertebrate animals. DDT and similar insecticides have changed populations of insects and of animals that feed on insects. The filling of ponds and swamps by man has destroyed other populations. His wartime trenches have bred in some regions new fauna of insects, amphibia and reptiles, as I myself observed not long ago. His artificial reservoirs have created new habitats for wild life. In short, the zoo as an artificial environment often differs only in degree from the changes in nature made by man.

If Dr. Spurway says that in the captured wild animals we select new ecotypes she is doubtless right. But it would be going too far to identify this selection with domestication, as she considers appropriate. As has already been emphasized, many possible domestication effects in the zoo can be counteracted by appropriate measures.

It is part of the task of the biology of zoological gardens to analyze the effects of artificial factors in the zoo environment. The further this analysis progresses, the better we are equipped to avoid extreme deviations from the wild-animal character. Up to now these deviations seem to have been so insignificant in most zoo animals that we may still safely call them wild animals. This holds especially for the numerous animals which have not yet bred in zoos and are obtainable only by capture.

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WILLIAM ROWAN HAMILTON

This 19th-century Irishman was a famous child prodigy who later became one of the greatest of all mathematicians. His calculus of quaternions has come to the fore in modern theoretical physics

by Sir Edmund Whittaker

After Isaac Newton, the greatest mathematician of the English-speaking peoples is William Rowan Hamilton, who was born in 1805 and died in 1865. His fame has had some curious vicissitudes. During his lifetime he was celebrated but not understood; after his death his reputation declined and he came to be counted in the second rank; in the 20th century he has become the subject of an extraordinary revival of interest and appreciation.

About his ancestry there is not much to be said. His father was a Dublin solicitor who defended the outlawed Irish patriot Archibald Hamilton Rowan and obtained a reversal of his sentence. From Rowan, who acted as sponsor at the baptism of the infant William, the boy received his second Christian name. The child was not brought up by his own parents. When he was about a year old, they decided to entrust his education to Mr. Hamilton's brother James, a clergyman settled at Trim, a small town 30 miles north of Dublin. Young William lived in Trim, with occasional visits to Dublin, until he was of age to enter the University.

Whether the credit must be given to his uncle's methods of education or to his own natural gifts, it is recorded that by the age of three William could read English easily; at five he was able to read and translate Latin, Greek and Hebrew; at eight he had added Italian and French; before he was 10 he was studying Arabic and Sanskrit. At the age of 14 he wrote a letter in Persian to the Persian ambassador, then on a visit to Dublin.

The boy loved the classics and the poets, but at the age of 15 his interests, and the course of his life, were completely changed when he met one Zerah Colburn, an American youngster who gave an exhibition in Dublin of his powers as a lightning calculator. "For a long time afterwards," wrote Hamilton later, "I liked to perform long operations in arithmetic in my mind; extracting the square and cube root, and everything that related to the properties of numbers." William resolved upon a life of mathematics. "Nothing," he declared, "so exalts the mind, or so raises a man above his fellow-creatures, as the researches of Science. Who would not rather have the fame of Archimedes than that of his conqueror Marcellus? . . . Mighty minds in all ages have combined to rear the vast and beautiful temple of Science, and inscribed their names upon it in imperishable characters; but the edifice is not completed; it is not yet too late to add another pillar or another ornament. I have yet scarcely arrived at its foot, but I may aspire one day to reach its summit."

In his diary there presently appeared such entries as "read Newton's *Life*" and "began Newton's *Principia*." At the age of 16 he made the acquaintance of Laplace's *Mécanique céleste*. (An entry in his journal around this time recounted: "We have been getting up before five for several mornings—that is, my uncle and I; he pulls a string which goes through the wall and is fastened to my shirt at night.") In 1823, preceded by rumors of his intellectual prowess, "Hamilton the prodigy" entered Trinity College at Dublin. There his progress was brilliant, not only on the examinations but also in original research. When he was only 21 years old he submitted to the Royal Irish Academy a paper entitled *A Theory of Systems of Rays* which in effect made a new science of mathematical optics.

In this paper Hamilton's aim was to remodel the geometry of light by establishing one uniform method for the solution of all problems in that science. He started from the already established principles that a ray of light always travels by the path that takes the least time (according to the wave theory) or the least "action" (according to the corpuscular theory) in going from one point to another; this is true whether the path is straight or bent by refraction. Hamilton's contribution was to consider the action (or time) as a function of the positions of the points between which the light passes, and to show that this quantity varied when the coordinates of these points varied, according to a law which he called the law of varying action. He demonstrated that all researches on any system of optical rays can be reduced to the study of this single function. Hamilton's discovery of this "characteristic function," as he called it, was an extraordinary achievement of scientific genius. He had originally projected it when he was 16 and he brought it to a form approaching completeness in his 21st year.

The communication of the paper was soon followed by a great change in Hamilton's circumstances. The chair of professor of astronomy at Trinity College, which paid an annual salary of 250 pounds and conferred on its occupant the title of Royal Astronomer of Ireland, was vacated in 1826 when its holder, the Reverend John Brinkley, was appointed to the Bishopric of Cloyne, once held by the great philosopher George Berkeley. Hamilton was elected as Brinkley's successor a few months later. The election of an undergraduate to a professorial chair was an astonishing event, and it led to some curious consequences. For instance, the Royal Astronomer was by virtue of his office an examiner for the Bishop Law Prize, a mathematical distinction open to candidates of junior bachelor standing, and thus came to pass the anomalous proceeding of an undergraduate examining graduates in the highest branches of mathematics.

While everyone acknowledged the unprecedented honor of Hamilton's appointment to the chair, opinion was sharply divided as to whether he was wise to have accepted it. In another year or two he would undoubtedly have been elected a fellow of Trinity College, with better financial and other prospects. What determined his choice was the consideration that the Royal Astronomership was practically a research appointment, involving very little in the way of fixed duties, while a fellow was required to become a clergyman and must soon have developed into a tutor and lecturer, with duties occupying most of his time. To be sure, the research equipment of the astronomical observatory was poor in the extreme, but what really was in the minds both of Hamilton and of the electors was not astronomy but an arrangement by which he could continue the theoretical researches of which the paper on *Systems of Rays* was such a glorious beginning.

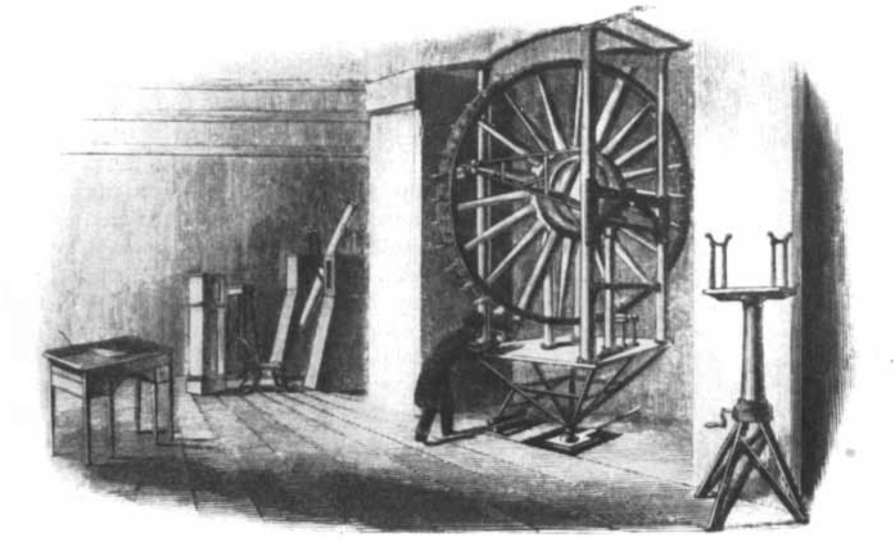
Hamilton did have the duty of giving a course of lectures on astronomy. In these it was his custom to discuss the relations of astronomy to physical science in general, to metaphysics and to all related realms of thought. His lectures were so poetic and learned that they attracted crowded audiences of professors and visitors as well as his class of undergraduates; when in 1831 there was some talk of his being transferred to the chair of mathematics, the Board insisted that he remain where he was. As inducement the Board raised his salary to 580 pounds a year and gave him permission to devote his research principally to mathematics.

In 1832 Hamilton announced to the Royal Irish Academy a remarkable discovery in optics which followed up his theory of systems of rays. It had been known for some time that certain biaxial crystals, such as topaz and aragonite, gave rise to two refracted rays, producing a double image. Augustin Fresnel of France had worked out the rules of double refraction. Now Hamilton, investigating by his general method the law of Fresnel, was led to conclude that in certain cases a single ray of incident light in a biaxial crystal should give rise to not merely two but an infinite number of refracted rays, forming a cone, and that in certain other cases a single ray within such a crystal would emerge as a different cone. He therefore proposed from theory two new laws of light, which he called internal and external conical refraction. They were soon verified experimentally by his friend Humphrey Lloyd, a Dublin physicist.

In 1834 Hamilton, then 29, wrote to his uncle: "It is my hope and purpose to remodel the whole of dynamics, in the most extensive sense of the word, by the idea of my characteristic function." He proceeded to apply this principle to the motion of systems of bodies, and in the following year he expressed the equations of motion in a form which showed the duality between the components of momentum of a dynamical system and the coordinates of its position. Only a century later, with the development of quantum theory, did physicists and mathematicians fully realize the importance of this duality.

In 1835 Hamilton received the honor of knighthood, and two years later he was elected president of the Royal Irish Academy. But his private life was less happy. Upon becoming a professor he had set up house with three of his sisters at the Dunsink Observatory on a hill five miles from Dublin. At the age of 26 he fell in love with Helen Maria Bayly, the daughter of a former rector in County Tipperary. She at first refused to entertain his proposal of marriage but ultimately accepted him, and the wedding took place on April 9, 1833. He had remarked in a letter to a friend on her "extreme timidity and delicacy"; these qualities were only too fully confirmed after the marriage. Lady Hamilton bore two sons and a daughter in six years, but she found herself unequal to the work of home administration and left Dunsink for two years to live with a married sister in England. She returned in 1842, but things became no better. Hamilton henceforth had no regular times for his

HAMILTON was portrayed by a contemporary artist with his mace of office as President of the Royal Academy of Ireland. He was Royal Astronomer of Ireland from 1826 to 1865.


MERIDIAN ROOM of the Dunsink Observatory, home of the Royal Astronomer, was depicted in 1845. The equipment was poor. Hamilton spent nearly all his time on mathematics.

meals, and he began to use alcoholic stimulants to a dangerous extent.

When I held Hamilton's chair, to which I had the honor of being appointed in 1906, many years after his death, I met many people who had known him. The countryside was full of stories about him. One of them concerns his administration of the 17 acres of farmland around Dunsink Observatory, of which the Royal Astronomer has control. Hamilton, who was town-bred, knew nothing of farming, but in order to supply his household with milk he bought a cow. After some time, in the ordinary course of nature, the yield of milk began to fall off. Hamilton went to consult a neighboring farmer. The farmer, knowing with whom he had to deal, said that the cow, as the solitary occupant of 17 acres, was suffering from loneliness. Thereupon Hamilton inquired whether it would be possible to provide her with companions, and the farmer graciously agreed, in recognition of a payment by Hamilton, to allow his cattle to graze on the rich pastures of Dunsink.

In spite of the unfavorable conditions of his life, Hamilton's scientific work went on. In 1843 he made a great discovery—the Calculus of Quaternions.

He was led to this discovery by long thought on the problem of finding a general rule for computing the fourth proportional to three straight line segments when the directions of those lines were taken into account. A line segment with a specified direction is called a vector. It was well known that a vector in a plane could be represented by a complex number; that is, a number formed of both real and imaginary numbers, or $x + y\sqrt{-1}$. (The square root of -1, an imaginary number, is usually written i, so that the expression becomes $x+yi$.) If we represent real numbers by distances on the x axis of a graph, then multiplication of any number by -1, changing it to the negative number, may be thought of as rotating the line segment 180 degrees, while multiplication by i, the square root of -1, may be thought of as a 90-degree rotation [*see illustrations on page 86*]. Thus imaginary numbers are represented on the y axis, and i may be considered a unit on that axis, or a "unit vector." Any vector in a plane may then be specified by a complex number giving its x and y components. Such a pair of numbers, known as a doublet, obeys the same algebraic laws as a single number: doublets can be added, subtracted, multiplied and divided according to the usual rules. Thus it is possible to calculate the fourth proportional to three vectors in a common plane: $V_1 : V_2 = V_3 : x$.

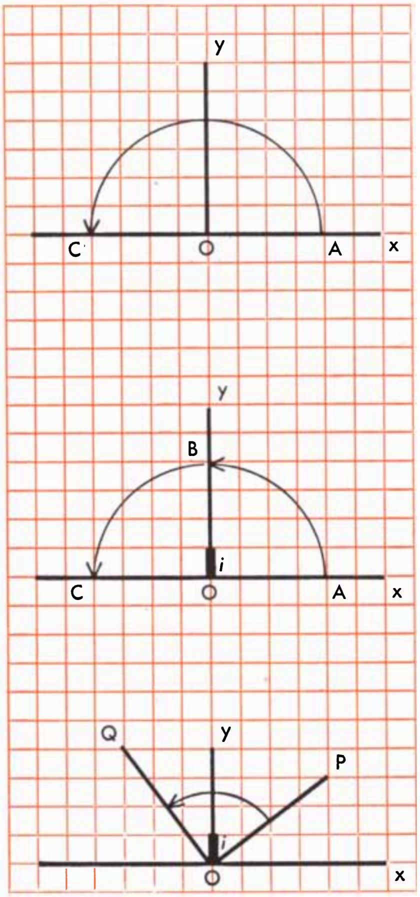
Hamilton conjectured that in three-dimensional space a vector might be represented by a set of three numbers, a triplet, just as a vector in a plane was expressed by a doublet. He sought to find the fourth proportional by multiplying triplets, but encountered difficulties. The younger members of the household at Dunsink shared affectionately in the hopes and disappointments of their illustrious parent as the investigation proceeded. William Edwin (aged nine) and Archibald Henry (eight) used to ask at breakfast: "Well, Papa, can you multiply triplets?" Whereto he was obliged to reply, with a sad shake of the head, "No, I can only add and subtract them."

One day, while walking from Dunsink into Dublin, Hamilton suddenly realized the answer: the geometrical operations of three-dimensional spaces required for their description not triplets but *quadruplets.* To specify the operation needed to convert one vector into another in space, one had to know four numbers: (1) the ratio of the length of one vector to the other, (2) the angle between them, and (3) the node and (4) the inclination of the plane in which they lie.

Hamilton named the set of four numbers a quaternion, and found that he could multiply quaternions as if they were single numbers. But he discovered that the algebra of quaternions differed from ordinary algebra in a crucial respect: it was *non-commutative.* This word calls for some explanation. When we multiply 2 by 3 we obtain the same product as when we multiply 3 by 2. This *commutative* law of multiplication, as it is called, is embodied in the algebraic formula $ab=ba$. It applies to imaginary numbers as well as to real numbers. It does not, however, hold for the calculus of quaternions, because the latter describes geometrical operations such as rotations. The illustration on page 87 shows why. It represents three mutually perpendicular axes, the y and z axes lying in the plane of the paper and the x axis extending toward the reader. The characters i, j and k represent unit vectors along the x, y and z axes respectively. Multiplication by i is defined as a 90-degree counterclockwise rotation in the plane of the paper; multiplication by j and k, as rotations in planes perpendicular to that plane. Now multiplication of j by i rotates j to k; that is, $ij=k$. But multiplication of i by j rotates i to $-k$; that is, $ji=-k$. Thus ij does not equal ji.

The surrender of the commutative law was a tremendous break with tradition. It marked the beginning of a new era. The news of the discovery spread quickly, and led, in Dublin at any rate, to a wave of interest amongst people of rank and fashion like the later boom in General Relativity in London, when Lord Haldane invited Einstein to meet the Archbishop of Canterbury at luncheon. Hamilton was buttonholed in the street by members of the Anglo-Irish aristocracy with the question: "What the deuce are the quaternions?" To satisfy them he published the delightful *Letter to a Lady*, in which he explained that the term "occurs, for example, in our version of the Bible, where the Apostle Peter is described as having been delivered by Herod to the charge of four quaternions of soldiers. . . . And to take a lighter and more modern instance from the pages of *Guy Mannering*, Scott represents Sir Robert Hazelwood of Hazelwood as loading his long sentences with 'triads and quaternions.' "

From this time until his death 22 years later, Hamilton's chief interest was to develop the new calculus. They were mostly sad and lonely years, owing to the frequent illnesses and absences of his wife. He worked all day in the large dining room of the Observatory house, into which from time to time his cook passed a mutton chop. (After his death scores of mutton chop bones on plates were found sandwiched among his papers.)

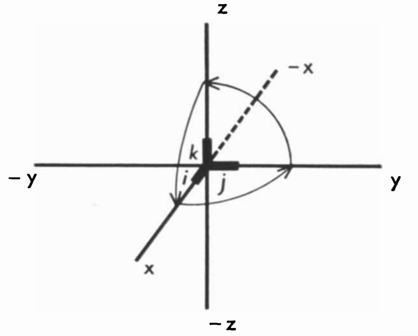


COMPLEX NUMBER, made up of a real number and an imaginary one, the square root of —1, is used to describe the length and direction of a line segment. When complex numbers are added, subtracted or multiplied, the process is equivalent to a geometrical operation, *e.g.*, rotation. In the diagram at the top the line segment OA, representing the number +4, is multiplied by —1, which changes it to the line segment OC, or —4. Thus multiplication by —1 is equivalent to rotation through 180 degrees. In the middle diagram multiplication by —1 is done in two steps, *i.e.*, multiplication by $\sqrt{-1}$ and by $\sqrt{-1}$ again. (The square root of —1 is usually written *i*.) Consequently multiplication by *i* can be considered rotation through 90 degrees. This leads to the idea of measuring imaginary distances on the y axis, as is indicated by making *i* the "unit vector" on that axis. The diagram at the bottom demonstrates that multiplication by *i* has the effect of a 90-degree rotation even if the starting point is not the x axis. The line segment from point O (x=0, y=0) to point P (x=4, y=3) is represented in complex-number notation as $4+3i$. Multiplying this number by *i* gives $4i+3i^2$, or $3-4i$. The latter number represents the line segment OQ (x= —3, y=4), or a 90-degree rotation of the line OP.

Hamilton's discovery was quickly followed by other new algebras, such as the Theory of Matrices, which is likewise non-commutative. Thus he started a glorious school of mathematics, though it was not to come into full flower for another half-century. I remember discussing in 1900 with Alfred North Whitehead whether quaternions and other non-commutative algebras had much of a future as regards applications to physics. Whitehead remarked that while all the physics then known could be treated by ordinary algebra, it was possible that new fields in physics might some day be discovered for which non-commutative algebra would be the only natural representation. In that very year this anticipation was started on the road to fulfillment. Max Planck introduced the quantum *h*, the beginning of the quantum theory. Now *h* is a quantum of action, and action was a central conception in Hamilton's system of dynamics. Thus the Hamiltonian ideas on dynamics began to come into prominence. But very slowly. When my book *Analytical Dynamics* was published in 1904, I was criticized severely for devoting a large part of it to such topics as the coordinates-momentum duality, action and other Hamiltonian ideas. The critics called them mere mathematical playthings.

The good work went on, however. The discovery of special relativity brought quaternions to the fore, because Arthur Cayley of Cambridge University had shown in 1854 that quaternions could be applied to the representation of rotations in four-dimensional space. His result yielded a particularly elegant expression for the most general Lorentz transformation. Moreover, the new discoveries again emphasized the importance of action, which preserves its form in different reference systems and is therefore fundamental in relativity physics.

Meanwhile, the workers in quantum theory were coming to realize that Hamilton's dynamical conceptions must form the basis of all rules of quantification. And in 1925 the other side of his work—his non-commutative algebra—was brought into quantum theory by Werner Heisenberg, Max Born and Pas-

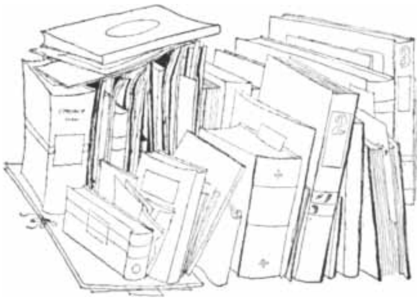


NON-COMMUTATIVE ALGEBRA is used to represent geometrical operations in three dimensions. A vector in three dimensions is represented in a system of coordinates with three mutually perpendicular axes (x points toward the reader, y and z are in the plane of the page) in terms of the unit vectors *i*, *j* and *k*. Multiplication by *i* is arbitrarily defined as meaning a rotation of 90 degrees in the plane perpendicular to the *i* vector, *i.e.*, the plane of y and z. Multiplication by *j* and *k* are similarly defined, as indicated by the arrows. Now it can be seen that applying *i* to *j*, which is to say $i \times j$, has the effect of rotating *j* into *k*. On the other hand, applying *j* to *i*, or $j \times i$, has the effect of rotating *i* into $-k$. So $i \times j = k$, and $j \times i = -k$. In other words, the multiplication is non-commutative: $i \times j$ does not equal $j \times i$.

cual Jordan, who showed that the ordinary Hamiltonian equations of dynamics were still valid in quantum theory, provided the symbols representing the coordinates and momenta in classical dynamics were interpreted as operators whose products did not commute.

Time has amply vindicated Hamilton's intuition of the duality between generalized coordinates and generalized momenta. This was strikingly shown in 1927, when Heisenberg discovered the Principle of Uncertainty, which is usually stated in this way: the more accurately the coordinates of a particle are determined, the less accurately can its momentum be known, and vice versa, the product of the two uncertainties being of the order of Planck's constant *h*.

Quantum-mechanical workers have generally tended to regard matrices rather than quaternions as the type of non-commutative algebra best suited to their problems, but the original Hamiltonian formulae keep cropping up. Thus the "spin matrices" of Wolfgang Pauli, on which the quantum-mechanical theory of rotations and angular momenta depends, are simply Hamilton's three quaternion units *i*, *j*, *k*. Arthur Conway has shown that quaternion methods may be used with advantage in the discussion of P. A. M. Dirac's equation for the spinning electron. Hamilton's formulae of 1843 may even yet prove to be the most natural expression of the new physics.



BOOKS

The correspondence of the Wright brothers as a reflection of their remarkable history

by James R. Newman

THE PAPERS OF WILBUR AND ORVILLE WRIGHT, edited by Marvin W. McFarland. McGraw-Hill Book Company, Inc. ($25.00).

A little more than a year after Orville Wright's death on January 30, 1948, his executors presented to the Library of Congress a collection of letters, diaries and notebooks unequaled in the whole of literature as a record of the evolution of an idea. The surpassing interest of these documents became known in 1951 when Fred C. Kelly published an admirable selection of about 600 of the 10,000 Wright letters in the book called *Miracle at Kitty Hawk*. McFarland's handsome two-volume work is a much more comprehensive undertaking. It presents nearly 1,000 papers from this collection and some 250 from that of the Wright brothers' friend and adviser Octave Chanute, acquired by the Library of Congress in 1932. The imagination and skill with which McFarland and his Library of Congress associates have edited and annotated this material cannot be praised too highly. They have composed, largely in the Wrights' own words, a beautiful step-by-step account of the invention of the first airplane that flew and a wonderfully candid autobiographical portrait of the two men who dreamed it, made it and flew it.

On Decoration Day, 1899, Wilbur Wright wrote to the Smithsonian Institution a historic letter, seeking information about publications on flight. Its opening lines were: "I have been interested in the problem of mechanical and human flight ever since as a boy I constructed a number of bats of various sizes after the style of Cayley's and Pénaud's machines. My observations since have only convinced me more firmly that human flight is possible and practicable." Wilbur was just 32, his brother Orville four years younger. They were the sons of the Reverend Milton Wright, a minister and later a Bishop of the United Brethren Church, and Susan Catharine Koerner, who had "a streak of the mechanical ability" of her father, known for his skill in the manufacture of farm wagons and carriages. Wilbur and Orville had never attended college or even formally graduated from high school, though each had attended the full time required for a diploma. At the time of Wilbur's letter to the Smithsonian the brothers were the proprietors of the Wright Cycle Company of Dayton, Ohio, engaged in the sale, repair and manufacture of bicycles. This business, opened in the spring of 1893, was moderately prosperous and afforded the brothers sufficient leisure to pursue their interest in flying. They had built flying toys which flew poorly, for reasons which they did not understand; they had read with admiration and excitement of the gliding flights of the great German pioneer Otto Lilienthal, who had crashed and died in 1896; they had carefully gone through a book on ornithology and were now ready to begin "a systematic study of the subject in preparation for practical work." "I am an enthusiast," Wilbur told the Smithsonian, "but not a crank in the sense that I have some pet theories as to the proper construction of a flying machine. I wish to avail myself of all that is already known and then if possible add my mite to help on the future worker who will attain final success."

Though the letter was written in the first person singular, when Wilbur said "I" he meant "we." The brothers, though distinct in personality, were bound together in an extraordinary symbiosis. They thought alike, had the same aspirations, sustained and anticipated each other. Both were slender, of medium height, with blue eyes and reddish brown hair. Wilbur had a dry humor, was tight-lipped and aggressive; Orville was easier and livelier. Inseparable companions in business and personal life, they shared everything from a bank account and sober habits to a streak of stubbornness and a genius for practical mechanics. Even their quarrels sounded more like self-reproaches than reproofs, and when they argued about their theories, which happened often, they usually convinced each other and, as their sister related, ended by "exchanging positions."

The pamphlets sent by the Smithsonian in response to Wilbur's letter made the brothers "highly enthusiastic with the idea of gliding as a sport." They read everything on the subject they could lay hands on and soon became convinced that the cause of the tragic failures of Lilienthal and the English aeronaut Percy S. Pilcher (also killed in a gliding crash) was their inability to maintain lateral equilibrium while in flight, except by the inadequate method of shifting the weight of their bodies. The lift of an airplane wing, as the Wrights realized, is a function of the angle it makes with the oncoming current of air. Since the motion of the air is apt to be tricky and variable, the center of air pressure is variable, causing one wing to go higher than the other and the craft to become unstable. The problem was to find a method of restoring equilibrium. At first it occurred to the Wrights to pivot the right and left wings on geared shafts at the center of the machine. One wing would turn upward in front when the other turned down, and the readjustment of balance would be automatic. But there seemed to be no way to make this device strong enough without making the glider too heavy.

One evening in July of 1899, Wilbur greeted Orville as he entered the house with the announcement that he had found a solution. "He demonstrated the method," wrote Orville, "by means of a small pasteboard box which had two of the opposite ends removed. By holding the top forward corner and the rear lower corner of one end of the box between his thumb and forefinger and the rear upper corner and the lower forward corner of the other end in like manner, and by pressing the corners together, the upper and lower surface of the box were given a helicoidal twist, presenting the top and bottom surface of the box at different angles on the right and left sides."

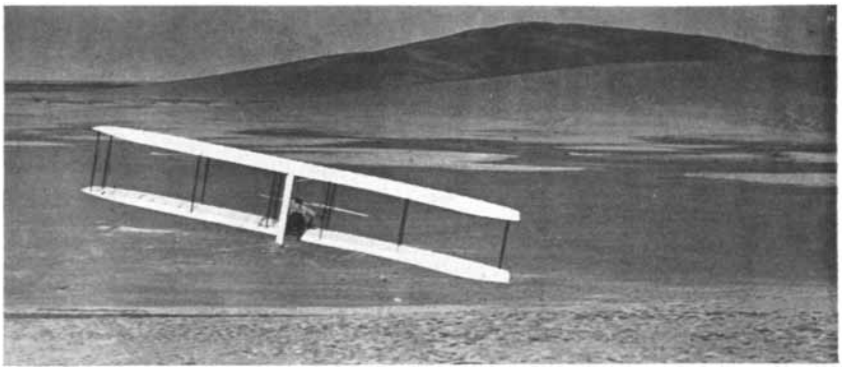
The brothers began immediately to build a five-foot biplane kite embodying this principle. Before the end of the month Wilbur had tested the model, manipulating its surfaces with cords and short sticks, and reported that it worked very well. Thereupon the Wrights decided to experiment with a "man-carrying machine" using their wing-warping device. The basic idea of adjusting the wings to different angles so as to obtain different lifts on the opposite wings was later applied in the design of all aircraft, though the Wrights' original mechanical device itself was little used. Within a few weeks after beginning their inquiries the brothers had conceived "their most radically important theory, on the correctness of which their future success and that of all aeroplane flight depended." Today the principle is known as aileron control: rotation about the longitudinal axis of the fuselage is achieved by a pressure differential on the extremities of the opposing wings.

On May 13, 1900, began the famous correspondence with Chanute. Octave Chanute, born in Paris in 1832, had come to the U. S. at the age of seven. He had had a long and successful career as a railroad civil engineer. His most notable achievement was the design and construction of the Kansas City Bridge, the first across the Missouri River. He had become interested in flying during a European trip in 1875, but not until 1889, when he settled in Chicago and founded his business for preserving railroad ties, could he afford the time and money to make serious and systematic aeronautical experiments. When Wilbur began the interchange of letters—announcing the Wrights' intention to test a full-sized glider—Chanute was the foremost figure of American aviation. This reputation stemmed not so much from what he had himself accomplished as from his great book *Progress in Flying Machines*—an exhaustive history of attempts to fly, an "elucidation of principles, a dispassionate analysis of failures as well as advances, a guide for contemporary and later experimenters." The Wrights of course had read his book and were now asking his advice as to a suitable locality for their experiments.

Chanute was most forthcoming in his reply. He sent the brothers some pamphlets, offered helpful suggestions and warmly encouraged their efforts. It was the beginning of a close relationship which lasted almost until Chanute's death in 1910. At the end they almost came to a complete break over petty grievances. The Wrights suspected Chanute of having furthered the impression they were "mere pupils and dependents" of his. They were also angry because he considered exorbitant the financial returns they demanded for their inventions. Chanute chided Wilbur because "your usually sound judgment has been warped by the desire for great wealth"; moreover he felt that the brothers were ungenerous in acknowledging the help he had given them. Chanute, to be sure, made no substantial technical contribution to the Wrights' work and appears never to have grasped fully the nature of their basic invention, but his unfailing encouragement, his confidence in them, his lucid writings and mastery of the literature undoubtedly were of great assistance. Had the brothers been less harassed and embittered by the unfair attacks and encroachments of others, they might have behaved more graciously toward Chanute. There was no meanness in them.

In the fall of 1900 the Wrights transported their equipment to Kitty Hawk, having learned from the U. S. Weather Bureau of the advantages of this locality for testing gliders. The North Carolina sand bar had steady winds, gently sloping dunes and reasonable weather at certain seasons. The brothers assembled their "soaring machine" on the beach and began their experiments. The graceful craft was a double-decker with a span of about 17 feet. Its weight with "operator" was 190 pounds. It cost $15 to make. The ribs were of ash, bent at one end

Orville and Wilbur Wright at the International Aviation Tournament in 1910



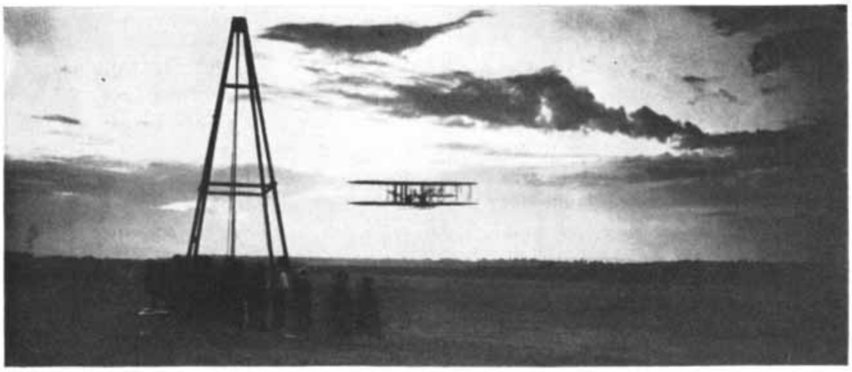
Wilbur Wright makes a turn during one of the glider experiments of 1902

somewhat like a hockey stick; the main cross pieces were of white pine; the covering of the surfaces was "French sateen . . . put on bias so that no wire stays were needed to brace the surfaces diagonally. . . . The uprights were jointed to the surfaces with flexible hinges and the whole machine trussed the long way, that is laterally, but not in the fore-and-aft direction. We used 15-gauge spring steel wire. By tightening the [key] wire every other wire was tightened. The surfaces were thus left capable of torsion, and this was the method we used to maintain lateral equilibrium. We laid down flat on the lower surface and maintained fore-and-aft balance by means of a forward rudder. We used no rear rudder; and neither horizontal nor vertical tails. . . ."

"Our first machine," Orville wrote from Kitty Hawk to his sister Catharine, "seemed a rather docile thing, and we taught it to behave fairly well." This was not a simple feat. The Weather Bureau had given the Wrights less than perfect information. They had expected winds of 15 miles an hour, but it turned out this figure was an average. Some days the wind blew at 50 to 60 miles per hour; other days there was dead calm. Although they had only brief spells of favorable weather for practice, they learned much. They thoroughly proved the efficiency of wing-warping to obtain lateral balance, and of the horizontal rudder for fore-and-aft control. They made careful measurements of lift drag and angle of attack. The experiments indicated that when the operator lay prone, air resistance was cut by more than 90 per cent. Moreover the practice was "perfectly safe and comfortable except for the flying sand." Although landings were sometimes made at speeds near 30 miles per hour, the machine was never damaged and "the operators did not receive a single bruise." The main defect of the glider was its inadequate lifting power. This might be due, the Wrights conjectured, to the porosity of the unvarnished surface covering and to insufficient convexity or camber of the wings. They could hardly wait for the next slack season in the bicycle business so that they might resume experiments with a new machine.

In July, 1901, they returned to Kitty Hawk. They were greeted by a storm which broke the anemometer cups at 93 miles per hour. After it had subsided, a miserable week was spent fighting mosquitoes, "which came in a mighty cloud, almost darkening the sun, buzzed like a mighty buzz saw" and bored through everything except horse blankets, under which the brothers sometimes had to take refuge for hours, in spite of the extreme summer heat. But Wilbur and Orville, attired as always in white starched collars, neckties and neat if not classy business suits, pushed forward energetically and good-humoredly with their business. A tent and workshop were erected, a deep well was bored, and the new machine assembled. With a wing span of 22 feet it was bigger, heavier and stronger than its predecessor. But, alas, it was much less manageable. While the lateral balance was good, lift was poor and the brothers were severely disappointed in the behavior of the glider when they attempted to circle.

They understood thoroughly the superiority of curved-over plane surfaces in lifting power; in the design of this machine they had increased the camber from 1 in 22 to 1 in 12 to conform to the shape prescribed by Lilienthal's tables of pressure. Much to their surprise, the machine required all the operator's strength and skill to prevent it from plunging into the ground—as Lilienthal's machine had—or rearing up so sharply as to lose all headway. But not for nothing had the Wrights spent dozens of hours carefully watching how hawks and buzzards held their wings when they soared on the wind. Now their observations saved them from disaster and led them to the correct explanation of the antics of their glider.



At Camp d'Auvours in 1908 Wilbur Wright made a record flight of one hour, 31 minutes

The Wrights had sharpened the curve of the wings' leading edge, in order to counteract the nose-diving tendency of the machine. They now noted, as Wilbur wrote: "In deeply curved surfaces the center of pressure at 90 degrees is near the center of the surface, but moves forward as the angle becomes less, till a certain point is reached, varying with the depth of curvature. After this point is passed, the center of pressure, instead of continuing to move forward with the decreasing angle, turns and moves rapidly toward the rear. The phenomena are due to the fact that at small angles the wind strikes the forward part of the surface on the *upper* side instead of the lower, and thus this part altogether ceases to lift, instead of being the most effective part of all, as in the case of the plane."

The Wrights reduced the camber to 1 to 18 and found that the machine responded promptly to even small movements of the rudder. They made successful glides of 366 and 389 feet. They sailed along boldly in winds of 20 to 25 miles an hour. But the brothers were far from satisfied. They had learned a great deal about control but their glider was still feeble in lifting itself off the ground and in staying aloft. Moreover, the warping of a wing to increase its angle of attack did not always produce the desired result: the wing sometimes fell instead of rising, which meant that turning became a chancy and unpredictable maneuver.

Their discouragement did not last long. On returning to Dayton they launched a program of thousands of experiments to establish reliable tables of lift and pressure and to determine the aerodynamic properties of various shapes. With homemade, brilliantly ingenious testing devices, including a wind tunnel, they measured the drag-lift ratio for various model airfoils, the effect on lift of varying the camber, the optimum shape for leading edges of the wing so as to reduce head resistance. "We don't hear anything but flying machine and engine from morning till night," their sister Catharine reported to her father. "I'll be glad when school begins so I can escape." Always practical, the brothers had no intention of ruining their bicycle business in pursuit of a dream. When Chanute, who was kept fully informed of their researches, offered financial assistance, Wilbur wrote: "For the present we would prefer not to accept it for the reason that if we did not feel that the time spent in this work was a dead loss in a financial sense, we would be unable to resist the temptation to devote more time than our business will stand."

At the end of August, 1902, they were back at Kitty Hawk with a new glider. It had a span of 32 feet and sported a rear vertical tail and a system of torsional gears to warp the wing surfaces. The glider had a tendency to go into a spin, but the brothers overcame the tendency with a major discovery—stabilizing the craft laterally by making the tail movable. One night the idea came to Orville of converting the fixed vertical tail to a rudder which during a turn could be swung toward the dipping wing to compensate for the increased drag imparted to the high wing by its greater angle of attack. At breakfast the next morning Orville described his idea to Wilbur. "Knowing Wilbur's unconscious habit of sometimes pushing his prerogatives as older brother and of assuming priority for himself in the conception of any new ideas, Orville fully expected his suggestion to be brushed aside with an 'Oh, yes, I was already considering that.' Instead, Wilbur listened attentively and remained silent for a minute or two. Then, without hesitation, he not only accepted the change but startled Orville by proposing the further bold modification of interconnecting the rudder wires with those of the wing warping so that by a single movement the operator could effect both controls. Thus, within a few hours, through the uncanny interplay of two remarkably sympathetic minds, all the essentials of the Wright control system were completed."

The trials were successful beyond expectation. On October 23 and 24, 1902, the brothers made 250 glides in winds up to 30 miles per hour. They were now ready to apply for patents on their machine and control system and to add the engine. Home again in Dayton, they invited bids for a gasoline engine which would develop eight to nine brake horsepower, weigh no more than 180 pounds and "be free from vibration." None of the manufacturers to whom they wrote was able to meet these specifications. The Wrights therefore designed and built their own motor. When they began to think about the propellers, they discovered to their consternation that all that had been written on screw propellers was worthless and they would have to build their own. It was hard to know where to begin. As Wilbur stated later, "with the machine moving forward, the air flying backward, the propellers turning sidewise, and nothing standing still, it seemed impossible to find a starting point from which to trace the various simultaneous reactions." But in a few months the marvelous siblings of Dayton had untangled the relevant factors and found a solution. They felt pretty cocky, and rightly; their propellers gave in useful work about two thirds of the power expended—a third more than had been achieved by such learned men as Hiram Maxim and the unfortunate Samuel Pierpont Langley. "Isn't it astonishing," Orville wrote to a friend, "that all these secrets have been preserved for so many years just so that we could discover them!"

The brothers tested their "little gas motor," tore it apart, rebuilt it again and again; they made cardboard figures and studied the principles of rotation; they rechecked all their experimental data and recalculated their load and lift tables; they redesigned ribs and spars and discovered to their surprise that the head resistance of uprights could be much more reduced by symmetrically rounding both front and rear than by rounding in front and tapering the rear to a sharp edge.

On September 25, 1903, they went once more to their Kitty Hawk camp. Orville spent the next morning "arranging kitchen and making 'French drip' coffee-pot, thus doing away with the use of eggs for coffee—quite a good thing when eggs are as scarce as they are now." The new flying machine they proceeded to build was "the prettiest we have ever made," as Orville wrote his father. It had a span of 40 feet 4 inches, a camber of 1 in 20, a wing area of 510 square feet and a length of 21 feet. It weighed 605 pounds. The wings, which had a 10-inch droop, were not symmetrical: the right wing was four inches longer than the left to provide additional lift for the engine (right of center) which weighed 34 pounds more than the operator (left of center). The motor had four horizontal cylinders of four-inch bore and four-inch stroke, with an aluminum-alloy crankcase and water jacket. The fuel tank carried four tenths of a gallon of gasoline. The engine with its magneto weighed 179 pounds, and its brake horsepower was 12. Owing to certain peculiarities of design, after several minutes' run the engine speed dropped from 1,200 revolutions per minute to 1,090 and the power to less than 75 per cent of what it was on cranking the motor. Even so, the Wrights were sure it would do its job.

October was a month of vicissitudes. Installing the engine and the propellers proved a heartbreakingly arduous task. The motor was cranky and missed so often that the vibrations kept jerking the propeller-shaft assembly apart. The magneto failed to produce a strong enough spark. One of the most stubborn problems was fastening the sprocket wheels to the propeller shafts; the wheels and the nuts loosened within a few seconds even when they were tightened with a six-foot lever. And the weather misbehaved as if Aeolus had decided to give the Wrights a final warning not to venture into an element where they did not belong. It was so cold that the brothers slept fully clothed—to shoes, hat and overcoat—under five blankets and two quilts beside a fire. Then a cyclone swept over Kitty Hawk, with winds up to 75 miles per hour. The main house almost rolled over on its back and the water rose six inches over the floorboards. But at last the weather cleared, the engine began to purr instead of hiccough, and with the help of a miraculous preparation known as Arnstein's hard cement "we stuck those sprockets so tight I doubt whether they will ever come loose again."

On December 14 the "flyer" was pushed out for its first trial. An error of judgment by Wilbur caused the machine to stall immediately after take-off and the front rudder broke on landing. But the repairs were easy, and the brothers were full of confidence. "There is now no question of final success," Wilbur wrote home.

Thursday, December 17, was a clear day with winds of 20 to 25 miles blowing from the north. A flag signal was hoisted to notify the men at the Kill Devil Life Saving Station that further trials were intended. The flyer was set on its 60-foot track, made of two-by-fours covered with thin strips of metal. (The Wrights had built it for $4; Langley's elaborate launching apparatus, which nine days before had deposited his "aerodrome" in the Potomac, had cost nearly $50,000.) At 10:35 a.m. Orville, decorously dressed, lay flat on his stomach in the cradle on the lower wing and the flight was ready to begin. The machine started down the track and took off, traveling at about 7 or 8 miles per hour, "just as it was entering on the fourth rail." Wilbur had been running alongside, holding the wing to give it balance; John T. Daniels, a Coast Guardsman, took a picture at the instant the craft left the track. The flyer leaped 10 feet into the air, lurched and wobbled. Orville struggled with the front rudder and tried to gain control against the buffeting of the 27-mile headwind. About 100 feet beyond the end of the tracks the craft suddenly darted to the ground, ending the flight. "Time about 12 seconds (not known exactly as watch was not promptly stopped)." The airplane—for at last it could properly be called that—was damaged on landing. Quick repairs were made. At 11:20 a.m. Wilbur took his turn and flew about 175 feet. He made a third and fourth trial, the last covering 852 feet.

Toward evening that day Bishop Milton Wright in Dayton received a telegram from his sons: "Success four flights Thursday morning all against twenty-one-mile wind [this was an average] started from level with engine power alone average speed thirty-one miles longest 57 seconds inform press home Christmas." It was signed "Orevelle" and contained a few other errors, but the Bishop got the idea. So did the press—after its fashion. The Cincinnati *Enquirer* had "flaming headlines"; *The Woman's Home Companion* and SCIENTIFIC AMERICAN wanted pictures; the Associated Press serviced its members with a faithful account taken from the Norfolk *Virginian-Pilot*, which included the statements that the operator had been seated in a navigator's car, that there was a propeller underneath the plane to give it an "upward push," and that Wilbur, seeing his brother ascend, had exclaimed "Eureka!" The Bishop gave out a biographical note:

"Wilbur is 36, Orville 32, and they are as inseparable as twins. For several years they have read up on aeronautics as a physician would read his books, and they have studied, discussed and experimented together. Natural workmen, they have invented, constructed and operated their gliders, and finally their 'Wright Flyer,' jointly, all at their own personal expense. About equal credit is due each."

There is not a tedious moment as one follows the brothers further through their flying exhibitions in Europe, their complex business negotiations, their court fights to sustain their patents, their attempts to sell Flyers to the Army. In financial affairs the Wrights were remarkably shrewd—a match for international munitioneers, foreign agents and domestic bankers. They grew rich and famous but were less spoiled by the high life than might have been expected. Sometimes they quarreled, Wilbur reproving Orville for being careless, Orville protesting Wilbur's older-brother high-handedness, but their love and sense of humor were unfailing restorers. They were superb flyers, courageous but never foolhardy. Their fascinating papers make clear why the Wrights were the first men to fly.

On May 30, 1912, Wilbur, aged 45, died of typhoid. Orville survived him by 36 years. But he could never bring himself, McFarland tells us, "to think of Wilbur in any other way than as being in the next room, ready at a call to join in whatever business was at hand." In his old age Orville told Fred C. Kelly: "I can remember when Wilbur and I could hardly wait for morning to come to get at something that interested us. *That's* happiness!"

Short Reviews

ORIGINS OF AMERICAN SCIENTISTS, by Robert H. Knapp and H. B. Goodrich. The University of Chicago Press ($7.50). THE YOUNGER AMERICAN SCHOLAR: HIS COLLEGIATE ORIGINS, by Robert H. Knapp and Joseph J. Greenbaum. The University of Chicago Press and Wesleyan University Press ($3.00). The first of these books is the report of an investigation "to discover what factors have in the past been most important in interesting undergraduate college students in science as a vocation." Based on a statistical analysis of the graduates of some 490 universities and colleges in the period 1924 to 1934, it comes to the conclusion that the institutions most productive of scientists in that period were "those of modest cost, middle and far western location, and drawing their students in good part from semirural regions." The authors therefore advance a "grass roots" hypothesis of the origin of American scientists. The second book, analyzing the origins of persons who won "postgraduate academic distinction" in science in the five years from 1946 to 1951, comes in the nick of time to rescue the reputations of the more expensive universities. Men and women "receiving awards in science tend to come in highly disproportionate numbers from institutions of high costs; in fact, for every sample, the highest fifth for cost of attendance is at least twice as productive proportionally as the remaining institutions." The authors suggest that the most likely reason for the reversal of pattern is that the leading Eastern schools of higher learning have undergone drastic changes in "intellectual climate" and student composition in the past two decades. The G. I. bill, expanded scholarship programs and the rise in the general level of income have enlarged the opportunities for young men and women of superior abilities throughout the country to pursue their studies at the more prominent universities.

Methods of Theoretical Physics, by Philip M. Morse and Herman Feshbach. McGraw-Hill Book Company, Inc. ($30.00). This two-volume treatise, based on graduate courses given by the authors at the Massachusetts Institute of Technology, is by far the most comprehensive survey of its subject yet published in the U. S. Its purview is the great sector of physics concerned with fields, wave functions, electromagnetic and acoustic potentials, "all of which are solutions of partial differential equations and are specified by boundary conditions." To make the treatise "reasonably self-contained," hundreds of pages have been devoted to mathematical topics such as functions of a complex variable, vector analysis, linear differential equations. This unfortunately has added greatly to the length and cost of the book; moreover, a student coming upon these subjects for the first time will still find it desirable to turn to monographs offering a less condensed treatment. A conspicuously attractive feature of the presentation is the authors' enlightened determination not to permit refined questions of mathematical rigor to obscure the physical problems for the solution of which the various mathematical tools have been devised. Their insistence on demonstrating at every turn the connection between physical and mathematical ideas marks an important reversal of the modern trend towards excessive abstraction. This excellent book will rescue many graduate students from the despairing conviction that to think of physics as having to do with the furniture of the earth is proof of having no imagination and being fit for nothing better than the law.

Science, Medicine and History, edited by E. Ashworth Underwood. Oxford University Press ($45.00). The 90 essays in these two opulent volumes are presented as a tribute to Charles Joseph Singer, long established as the foremost British historian of science and medicine. The wide range of subject matter is singularly appropriate in view of the breadth of Singer's own researches and the sweep of his erudition. V. Gordon Childe writes on the constitution of archaeology as a science, A. D. Lacaille on the evolution of the knife, G. E. Gask and John Todd on the origin of hospitals. There are essays on medical practice in Anglo-Saxon England, on nautical science in the Renaissance, on the history of Albrecht Dürer's famous rhinoceros in zoological literature, on the psychiatry of Paracelsus, on the history of distillation and combustion, on dental anatomy from Aristotle to Leeuwenhoek, on crystallography, Schopenhauer's contribution to biological theory, the polar explorations of the 19th-century U. S. physician Elisha Kent Kane. Among other items of uncommon interest are Joseph Needham's discussion of the philosophy of science in ancient China and medieval Arabia and a delightful journey of reminiscence by the late Sir Charles Sherrington, in which appears the now celebrated anecdote of his saving the life of his 8-year-old nephew, stricken with diphtheria, with the help of some "homemade" antidiphtheric serum drawn from a horse Sherrington kept in a London stable near his home. Illustrated with more than 100 halftone plates and numerous text figures, this is a sumptuous treasury of the history of science.

The Sexual Offender and His Offenses, by Benjamin Karpman. Julian Press, Inc. ($10.00). This survey of sexual abnormalities is by the chief psychotherapist of St. Elizabeth's Hospital in Washington, D. C. The first part of his large book is a digest of the technical literature from 1912 to 1951; the second part presents his own views, based on 30 years of clinical experience and psychoanalytic practice. "I have accepted," he says, "the original Freudian approach, eschewing for the most part other approaches, such as that of cultural analysis, because I found the strictly analytical biological approach far more remunerative in results than any other that I have tried—and I have tried them all."

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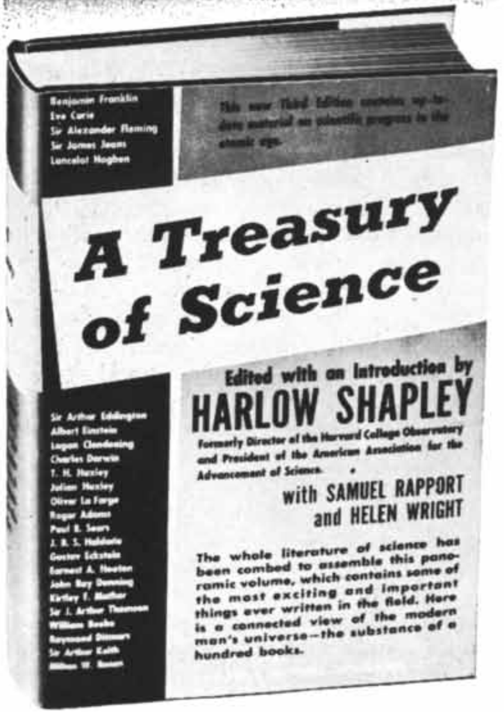

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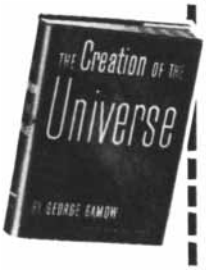

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THE AMATEUR SCIENTIST

About a hygrometer made from a flower pot, and huge telescopes with compound mirrors

Conducted by Albert G. Ingalls

Fred Lichtgarn is a Chicago inventor. Among his many inventions he takes greatest satisfaction in the wired fragment of pottery shown in the illustration on the opposite page. It is the "sensing" element of an electrical hygrometer, the first instrument ever made that can measure humidity changes promptly. In constructing it from a broken flower pot Lichtgarn proved once more that the amateur yields to no man when it comes to making ingenious use of materials.

The invention stemmed from Lichtgarn's application to the U. S. Weather Bureau some years ago for a job in weather research. He was told that preference was given to applicants with formal training in meteorology. In lieu of the training he made up his mind to impress the prospective employer with his talent for invention. A single visit to a weather station showed him that the field was wide open. "Meteorologists," says Lichtgarn, "live with instruments handed down in principle from the 1700s. Many observers take pride in pointing to 'triple recorders' last manufactured at the end of the 19th century. The field of weather instruments is an inventor's paradise."

After a detailed study Lichtgarn decided that the greatest room for improvement was available in the field of the gadgets used for measuring water vapor. He went to work on that problem and three years later came up with his hygrometer. The invention not only is something basically new in weather instruments but adds another member to the family of sensing elements for measuring instruments and automatic machines generally—a family which includes the gyroscope, accelerometer, thermistor, photoelectric cell and other devices. Incidentally, after patenting his invention Lichtgarn did not take the weather research job.

"That experience," he writes, "taught me that you don't need a million-dollar laboratory or a job with the government to do research. I also learned that some of the most interesting and challenging puzzles cost the least. I was astonished by the complexity of an apparently simple fragment of fired clay. Just try to learn why some ceramic materials behave as they do in the presence of water vapor! From past experience I knew that some materials were poor electrical conductors, and I was familiar with the distinction between a semiconductor and a leaky insulator. But it had not occurred to me to find out why and how a leaky insulator leaks until I got the idea of substituting one for the conventional hygrometer and psychrometer.

"It did not take long to reach the conclusion that a replacement for these instruments would have to be found if our knowledge of weather was to make much progress. In the days when meteorologists confined their activity to the study of large, slow-moving masses of air, the old instruments were adequate. After assembling approximate measurements of relative humidity, barometric pressure, temperature and wind direction from a number of observing stations, the forecaster could make only a rough estimate of the coming weather.

"Within the past two decades, however, interest has grown in the fine-grained structure of the atmosphere. Meteorologists now want a detailed picture of conditions in the atmosphere throughout a 10-mile vertical cross section above the station. Micrometeorologists demand a running account of changing events in the first 10 feet above the surface!

"It is one thing to measure various points within a slowly drifting air mass 500 miles in diameter and quite another to get the same picture of a swirl 50 feet across. Time works against you. There is no great problem in measuring rapid changes in temperature, pressure or wind, for good, quick-acting thermometers, barometers and wind vanes are available. But moisture measurements are something else again. The hair hygrometer and psychrometer act slowly. They tell you what the humidity *was*, not what it *is*. Recordings of relative humidity by a hair hygrometer in a radiosonde, for example, may lag behind those of temperature by a time equivalent to 1,000 feet of the instrument's ascent.

"The hair hygrometer is generally insensitive to sharp changes in humidity at the boundary of horizontal air masses. It is based on the principle that a hair stretches or shrinks as it absorbs or loses water vapor. Human hair, preferably blonde, is best. The changes in length are communicated through a system of levers to a pointer or a recording pen. Accuracy is adversely affected by the age of the hair, the amount of pollution to which it has been exposed, the mechanical condition and design of the lever system and the rate at which the boundary layer of air is changed. The instrument is not reliable at temperatures below freezing and does not work in the region of supersaturation.

"In many respects the sling psychrometer is no better. No basic improvement has been made in this device since its invention some 200 years ago. It is based on the principle that water evaporates at a rate proportionate to the amount of water vapor in the air. It employs two thermometers as sensing elements. The bulb of one is enclosed by a moistened wick. Heat lost by evaporation from the wick causes a difference of temperature indication between the two thermometers and enables an observer to calculate the relative humidity. During use the instrument is swung rapidly to prevent air in contact with the wick from becoming saturated. If the swinging is continued until the wet bulb reaches minimum temperature, if the wick is of proper texture and fits snugly and is not contaminated, and if the observer reads the thermometers promptly, he learns eventually and with considerable accuracy what the relative humidity used to be.

"Having dismissed the possibility of

making a substantial improvement in either of these instruments, I looked for some better way of measuring water vapor and finally hit on the principle of adsorption. It is well known that water vapor is adsorbed strongly by many materials, including such interesting substances as powdered glass, to which molecules of water vapor will cling even after the glass is heated to a dull red.

"I knew from previous experience that charcoal has a strong adsorptive affinity for water vapor. It is often used as the adsorbent in the gas traps of high-vacuum systems. The traps are filled with pulverized charcoal. When cooled by liquefied air, they have an immense capacity for soaking up unwanted gas. Charcoal owes much of its effectiveness as an adsorbent to its porous structure, which gives it a tremendous surface area per unit of volume—as much as 5,000 square feet per ounce. The pores are large in relation to the size of gas molecules. Hence the gas diffuses through the charcoal easily and is uniformly adsorbed over the entire surface. The normal thermal movement of the carbon atoms limits the number of gas molecules that can be adsorbed at a given temperature. In general, the amount of adsorbed gas varies inversely with the temperature. Of equal interest is the fact that the forces of adsorption dislodge some of the electrons associated with molecules of water vapor, thereby creating ions—carriers of electrical current. The conductivity varies in direct proportion to the number of ions, hence in proportion to the amount of adsorbed water vapor.

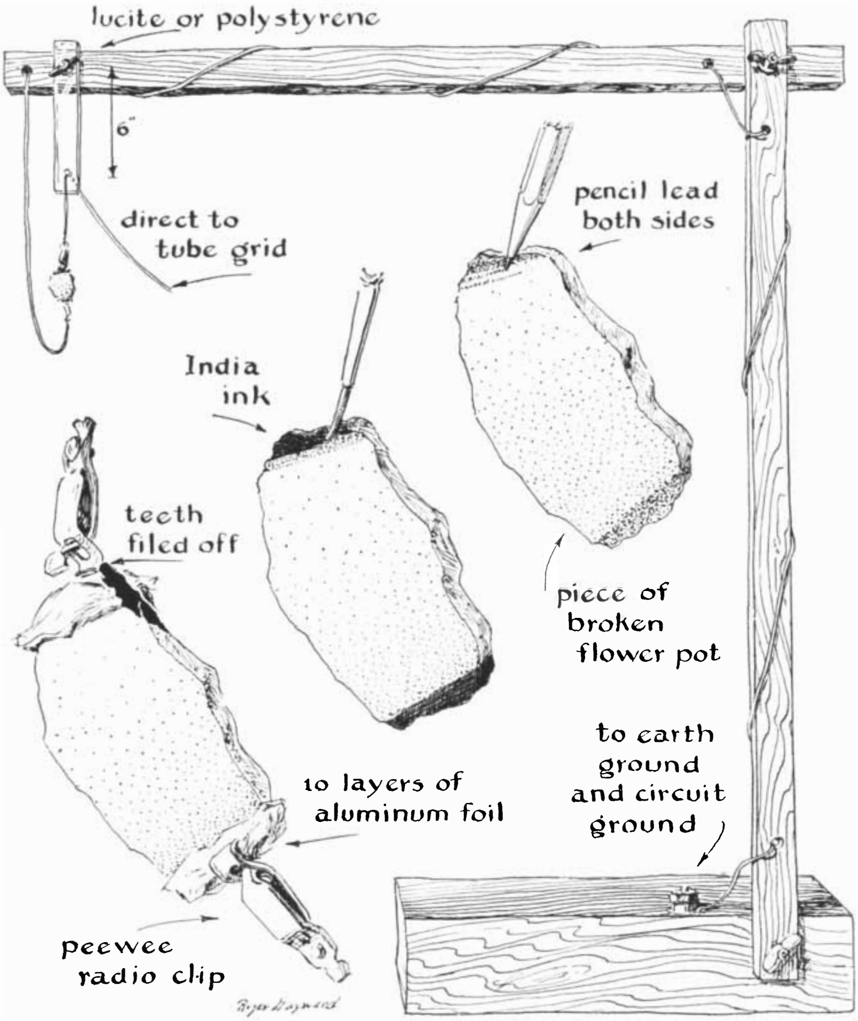
"As I visualized the adsorbent action, increases in humidity would bring fresh molecules of vapor to the surface of the adsorbent. Some molecules would attach themselves to the adsorbent momentarily, only to be dislodged by thermal agitation. Others would then occupy the vacated places. The interchange would be continuous. Decreases in temperature would enable a greater number of molecules to adhere. Decreases in humidity would reduce the supply of molecules and more would be lost from the surface than gained. In short, each change in temperature or water vapor, no matter how small, would trigger an automatic readjustment of the adsorbed layer which would continue until the interchange reached equilibrium at a new and constant level of activity. Because this action takes place at the molecular level, an instrument based on it should be extremely sensitive.

"The next step was that of finding a porous solid which was both a good insulator and a good adsorber of water vapor. Charcoal did not meet the requirement, because it is a much better electrical conductor than ionized water vapor. In addition, the ideal material would have to be physically strong and inert to water vapor. Many substances, such as silica gel, alumina and charcoal, adsorb water vapor readily when their temperature is dropping but they do not release it at a proportionate rate with increases in temperature. Hence, as a final requirement, the affinity of the desired adsorbent must vary in proportion to temperature—because relative humidity is the measure of the amount of water per unit volume of air in relation to the capacity of the air to hold it in the form of vapor at a given temperature.

"It occurred to me that a ceramic material, if underfired, might combine the necessary porosity and insulating properties—at least for a rough check of the idea's soundness. A likely candidate was right at hand in the form of a broken flower pot.

"The first test was made with a small piece measuring approximately an inch wide and two inches long. An electrical connection was made at each end through a dab of India ink rubbed over heavily with soft pencil lead and covered by a few thicknesses of tinfoil held in place by "peewee" clips (with the teeth filed off). The clips served as terminals [*see illustration below*]. It was obvious that the resistance of the element was far beyond the range of a conventional ohmmeter: a flower pot can be used as an insulator of fair quality.

"This posed the problem of developing an experimental voltmeter of the vacuum-tube type sensitive to currents on the order of a hundredth of a microampere. The circuit adopted is shown on the next page. It was made flexible with respect to both input resistance and current so that various adsorbent materials could be tested. Experience taught the



A hygrometer which uses a piece of flower pot to measure changes in humidity

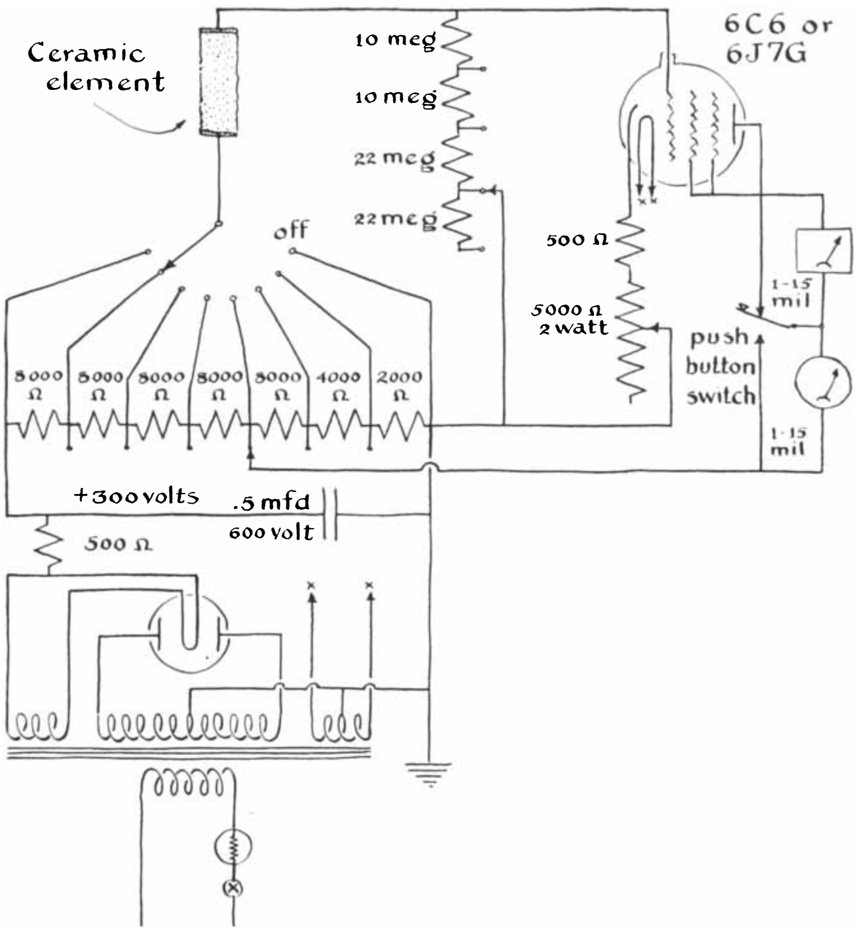


Diagram of the circuit for the electrical hygrometer

wisdom of using two meters in the circuit: one a conventional moving coil type, the other based on the principle of the iron vane, which is almost burn-out proof. The delicate coil-type instrument can be switched out of the circuit until the approximate resistance of an unknown adsorbent has been established. The insulation of the wiring, particularly that of the input leads, must be of the best quality, preferably polystyrene, Teflon or air. Any vacuum tube of the 6C6 or 6J5G type with the grid terminal mounted on the glass envelope works satisfactorily.

"With this circuit complete and the ceramic connected, the indicating meter responded perfectly to a rise or drop in relative humidity. During testing it was found that the element measured wide changes in relative humidity outdoors in temperatures as low as 5 degrees below zero Fahrenheit—well beyond the range of conventional hygrometers. I learned later that the optimum value of grid resistance varies with each adsorbent material and each range. These values must be found experimentally. When the adsorbent is an underfired flower pot (soft and yellowish in color), an input resistance of 42 megohms will generally give an on-scale indication of relative humidities over the range from 30 to 90 per cent. This value may be increased to 64 megohms for air drier than 30 per cent relative humidity and decreased to 10 megohms or less as saturation is approached.

"The cathode bias resistor serves as the 'zero' reference adjustment and is set for an arbitrary current of two milliamperes when the applied voltage switch is in the 'off' position.

"In effect the sensing element simultaneously measures the water vapor and the temperature of the air. Hence it is important to shield the element from sources of radiant heat. It is interesting to observe the response caused by a lighted candle at a distance of 10 feet.

"Those who enjoy original experiments will find electrical hygrometry a rewarding field. A beginner can gain experience quickly with almost no cash outlay by testing various pottery elements and calibrating them against a homemade sling psychrometer. A thick element may require as much as 10 minutes to reach equilibrium after a sharp change in humidity. Short, bulky ones work better in dry air and long, thin ones in the region of saturation. They can be shaped easily on a carborundum wheel.

"More interesting than pottery fragments are elements you can make yourself. Various raw clays are available in small amounts from artists' supply stores, drug stores, chemical supply houses and building supply dealers. These can be mixed with various substances (listed in reference texts of ceramics techniques) that affect porosity. Their effect on ionization and adsorption must be determined by experiment. Commercial kilns specializing in firing work for amateur artists and ceramics hobbyists can now be found in most communities. The average firing time and temperature for most elements will run about 60 hours at 1,400 degrees F. The temperature must be kept below vitrification.

"The over-all range of the instrument can be increased by using combinations of elements and by varying the electrical constants. A group of thin plates sensitive to low humidity can be connected through a resistor of high value to a single element designed for the high range. The input circuit of the meter is connected across the single element. The series resistor prevents the thin plates from acting as a short circuit in wet air. When operating in dry air the single element becomes an insulator; thus it does not affect the operation of the multiple element. Five or more elements, each designed for a portion of the humidity range, can be combined similarly in a single instrument which will cover a temperature range from −30 to over 100 degrees and from 20 per cent relative humidity to well into the region of supersaturation. There is no simple method of calibrating the instrument for measuring air in the supersaturated state, but the ceramic element continues to indicate in this region.

"The use of electrical hygrometry should appeal strongly to many amateurs—to weather observers, for example, particularly those specializing in micrometeorology. So far as I know, little if any effort has been made up to now to combine the electrical hygrometer with other sensing elements for automatic recording of complex aspects of climate such as soil evaporation, frost prediction and similar meteorological profiles.

"Finally, the unit should find wide application among amateurs who enjoy working in the field of automatic control. Like the thermostat, which controls the output of the furnace and room temperature, the electrical hygrometer can make humidifiers and desiccators self-controlling—a possibility which should appeal to those who operate greenhouses, incubators, 'dry' rooms and other enclosures in which a uniform atmosphere is essential."

The fact that the building of a telescope with a composite mirror 500 inches in diameter was seriously considered recently by certain U. S. astronomers has been an open "secret" to the whole astronomical and optical world. Many who would have enjoyed watching the costly experiment (without participating in its risks) have expressed disappointment that the project was given up. It is said that those who were to build it were discouraged by other astronomers.

The British optical designer E. H. Linfoot once explained the cautious conservatism of the average astronomer regarding unconventional telescopes. "None but a working astronomer is really qualified to pass judgment on a telescope design, and few astronomers have a sufficiently strong interest in optics to wish to experiment with new ideas in this field. It is only once or twice in a century that the average observatory can raise the money to invest in a new large telescope, and it is hard to blame a director who, after spending years of heartbreaking negotiation to obtain an endowment, prefers to spend the funds he has raised on something he knows a good deal about already. Nevertheless, this attitude has had unfortunate consequences in the past." George Ellery Hale, the builder of three great observatories, who had an optician's and mechanic's first-hand understanding of instruments, privately spoke of the same unfortunate consequences.

However, an amateur can experiment with a certain kind of large telescope that does not cost millions of dollars. This poor man's large telescope has a low-cost composite mirror and needs almost no mounting. If you could subtract from a large telescope, such as the 200-inch, all the immense mechanism that moves the massive mirror to compensate for the rotation of the earth, you would have extremely little mechanism left to be bothered with. There would be only a plate holder and a miniature mechanism, no larger than an electric clock, to move the plate slowly. In such a design the earth's rotation moves the fixed main mirror. Because it is rigidly supported, the mirror need be no more than one inch thick, and may consist of a mosaic of small inexpensive mirrors at the bottom of a deep pit.

The drawback of such a telescope is its limited scope; it can photograph only a narrow band around the heavens. Yet such a telescope would be so cheap that a chain of them could be built in different latitudes to cover a large part of the sky for less than the cost of a single conventional telescope of equal size. Six of them, spaced at 115-mile intervals, could photograph the heavens above California or Italy. Such telescopes, proposed by the Italian astronomer Guido Horn-D'Arturo and by the Finnish astronomer Y. Väisälä, were described in this department in January, 1951, and aroused more than the usual response from readers.

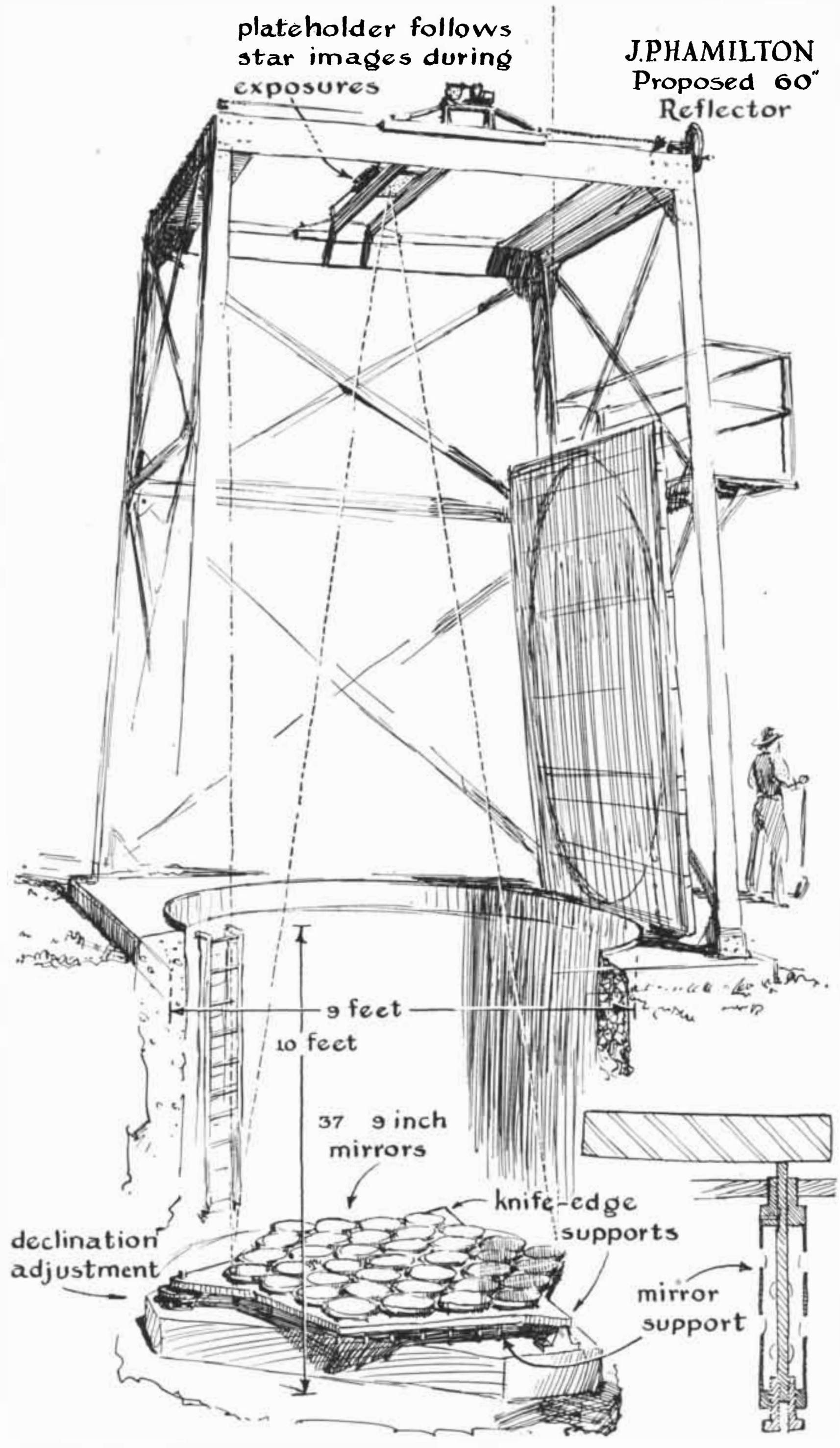
After reading the description, J. P. Hamilton of the Astronomical Society of Victoria, Australia, contributed to the Society's *Journal*, of which he is an editor, a scheme for a large telescope of this type which any group of amateurs could build [*see drawing on next page*]. The triangular support for the 37 mirrors has pivots at two of its apexes, while the third has a screw by which a 1.4-inch vertical motion alters the declination by 1⅓ degrees. The plate holder and its clock drive at the top of the tower are correspondingly shifted by a hand crank. By tilting the mirror the telescope may be made to cover three adjacent bands of the sky with a total width of four degrees. The blanks for the mirrors would be dealt out to the members of the society to be ground and polished as spheres. The central mirror would be given a radius of curvature of 820 inches, and the 37 spheres together would approximate a paraboloid if the six spheres that surround the center had a radius of curvature of 820.025 inches, the next 12 had 820.1 inches and the outer 18 had 820.22 inches. However, since it is difficult to grind long-focus spheres with a precision beyond one part in about 400 of the radius of curvature, the attainable precision would be only within about two inches, corresponding to 1.5 fringes in a test by interference made on the flash-polished fine-ground mirrors.

Hamilton anticipates that the most difficult problem would be adjusting the mirrors to a coincident focus. This would be accomplished by differential screws in the mirror supports, each turn lifting or lowering the mirror one thousandth of an inch. The collimation would be held stable by convexing the backs of each mirror concentric with the front. If the mirror shifted sidewise, the image would then not shift. This simple solution of an old problem, hit upon by F. J. Hargreaves and others of the British Astronomical Association, might profitably be used on all telescope mirrors.

Apparently among amateur astronomers in the antipodes human nature is the same as in the U. S., for Hamilton urges that the work of digging the deep pit be rationed so that all members of the group may enjoy the exhilaration.

H. E. Dall has pointed out that while the composite mirror will, as Horn-D'Arturo admits, give somewhat enlarged star images, photographically it should be little inferior to a single paraboloidal surface, because atmospheric turbulence usually limits high resolution.

Hamilton provides for a suction fan and duct to bring surface air to the bottom of the pit. But Roger Hayward, the illustrator of this department, says that instead of worrying about ventilation or temperature variations the telescope builders should rejoice at the virtues of



A fixed-mirror telescope planned by Australian amateurs

What General Electric people are saying . . .

F. E. CREVER
T. TROCKI

Mr. Crever is Manager—Engineering and Projects Department—Knolls Atomic Power Laboratory.

Mr. Trocki is Manager—Coolant Systems Sub-Section, Knolls Atomic Power Laboratory

". . . Ship propulsion appears to be the earliest practical application for a mobile atomic power plant and consideration of some fundamentals of a nuclear power plant will make the reasons apparent. As conceived today, a nuclear power plant differs from a conventional plant mainly in the method of heat production and heat transfer to a thermodynamic fluid, which is expanded in turbomachinery to produce power in the conventional way. In a plant using steam as the thermodynamic fluid, the nuclear reactor and steam generation equipment will replace the boiler and its accessories. Although the reactor core itself can be of relatively small dimensions, the shielding required around it increases the overall volume and weight of a reactor by a considerable factor. Furthermore, the reactor coolant and heat transfer fluid is made radioactive in passing through the reactor and all of the machinery through which it flows must be shielded. The shielding around the reactor core proper is called the primary shield, and the shield around the heat transfer equipment, the secondary shield. As the amount of shielding is practically independent of power output, a nuclear power plant of low power will be penalized excessively with respect to its power output. As the power output of a reactor-steam generation plant is increased, the equipment volume and shielding around it does not increase in direct proportion to the power; hence, a more favorable relationship is reached between power output and plant space and weight. Power plants for propulsion of larger power ocean-going vessels (of the order of 10,000 HP and above) are of sufficiently large power output to fall within the favorable range for a nuclear power plant of current design.

at the AIEE, New York

A. W. EADE
J. J. FRAIZER

Mr. Eade and Mr. Fraizer are with the Meter and Instrument Department

At the high speeds military planes fly today, the pilot simply doesn't have time to read indicators and coordinate information presented to him. To offset this situation, many new flight-control systems are presently undergoing development.

A good example of what is taking place is the automatic jet-engine control system developed by GE for the North American F86D Sabrejet. Here seven separate measurements are integrated, allowing the pilot to increase or decrease his thrust by simply moving a throttle; there's no danger of his overspeeding or overheating the engine.

Many proposals have been made to consolidate instruments so that one indicator would serve where formerly three or four were needed. Again, for example, an engine-performance indicator has already been proposed that will replace four separate indicators. This single indicator will at a glance show engine speed and temperature and oil and fuel pressure. The fuel and oil pressure portions of this gage would merely be OFF-ON devices, with a green flag indicating safe, and a red flag unsafe, pressure ranges. On the surface this appears to be a particularly good feature, for airmen often only glance at an accurately marked gage to check the pointer's relative position.

The progress made in the first 50 years of flight has been nothing short of astonishing. And there's reason to expect that it will continue to be even more so in the future. So far as instrumentation is concerned, you can look for a greater consolidation of instruments as the speed of flight moves upward and more use of flight-control systems in place of individual instruments and controls.

G.E. Review

G. R. FUGAL

Mr. Fugal is Manager—Employment Practices—Employee and Plant Community Relations Services

Group-administered safety education, as generally utilized by industry, is relatively ineffective. It does not really accomplish what management thinks it accomplishes. A general redirection of effort toward a continuing, individualized, personalized instruction is needed. The effectiveness of this type of training has been demonstrated.

The problem of training the employee to work safely is not so much the act, for example, of teaching him to put on his gloves. It is more than that. There is the additional factor of establishing in the employee's daily conduct the habit of wearing his gloves. Further, management must recognize that the factors of skill and understanding can be trained into the employee only with diligence and patience. Such learning takes a long time, and management must discard its ideas that these factors that enter so definitely into the safety-training activity can be acquired by the employee through the "shot in the arm" variety of industrial education.

During recent years increasing numbers of educators have campaigned for individualized instruction in the schoolroom, pointing to the superior results obtained over other methods. This experimentation provides an industrial education counterpart to the claims advanced by the formal educators in that the great individual differences in the attitudes, abilities, and habits of workers are recognized.

at the Lowell, Mass. Industrial Safety Council

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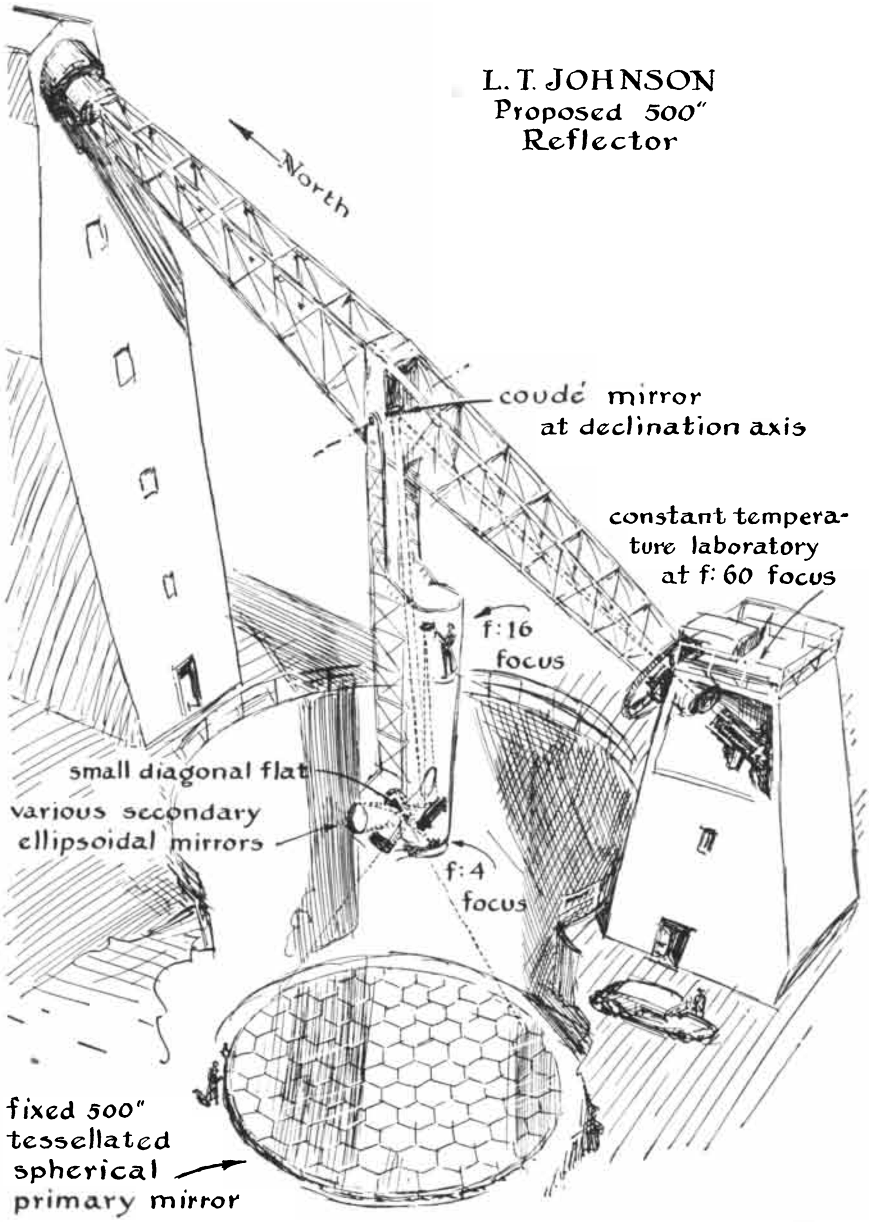

A large zenith telescope with a mirror moved by the earth

a pit full of still air: "Stirring it up with a blower would be to throw away nature's gift. The secret of the success of the spectroheliograph on the 150-foot sun tower on Mount Wilson is that the apparatus is in a pit where the air stratifies, with cold air on the bottom, and is very stable. Hence it would seem best to bury as much of the instrument as possible."

A telescope maker who likes to fool with unconventional telescope designs is the widely known planetary observer Lyle T. Johnson of La Plata, Md. The drawing above pictures one of Johnson's imaginative creations. As in the Hamilton telescope, the primary mirror is fixedly attached to the rotating earth at the bottom of a pit. It is a mosaic of narrowly separated hexagons or tesserae (tiles). As the earth rotates, the $f/2$ cone of rays reflected from a star field or object by the large mirror moves eastward. The observer's cage is kept in pace by its drive. It has swing enough for a two-hour exposure. During half an hour of the exposure, while the object is near the zenith, the whole of the 500-inch mirror sends its light to the plate; the rest of the two hours it catches part of the light. The cage may also be swung at right angles (north and south) 11½ degrees each side of vertical. Johnson says that this telescope could collect more light than the 200-inch for a period of more than an hour. A 700-inch mirror would greatly increase the range in both directions. He is also evolving other designs.

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