SCIENTIFIC AMERICAN

ARCTIC FLOWERS

FIFTY CENTS

February 1956

Twinkle twinkle...

. . . little star,
How I wonder what you are . . .

A child's curiosity. How you drove Mom and Dad nearly to distraction with questions, questions, questions.

Like Mom and Dad, research scientists live in a realm of questions, questions, questions. When they find an answer, however, it satisfies more than curiosity . . . it is progress.

During the past 25 years, Shell scientists have found many answers. Among them: a new way of making glycerine, Epon® resin for plastic tools and dies, ketone solvents for automotive lacquers and direct injection of ammonia fertilizer into soil and irrigation water.

Through research in chemistry, Shell Chemical joins hands with industry and agriculture to bring you a brighter, richer tomorrow.

The Great Nebula in Andromeda.
Painted by Chesley Bonestell

Shell Chemical Corporation

Chemical Partner of Industry and Agriculture

NEW YORK

SHELL

CORNING GLASS

BULLETIN FOR PEOPLE WHO MAKE THINGS

CORNING GLASS WORKS, 49-2 Crystal Street, Corning, New York

Please send me the following material:

- ☐ Booklet: "Glass and You."
- ☐ Bulletin IZ-1: "Glass . . . its increasing importance in product design."
- ☐ Information on the VYCOR brand glasses.

Name_____

Title_____

Company_____

Address_____

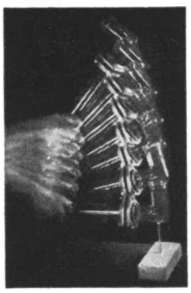
City_____ Zone_____ State_____

How to engineer a platypus

A happy combination of purposeful practicality is the furry platypus with its webbed feet, beaver's tail, and duck's bill.

A lot of our customers, to their continuing delight and profit (we hope), have discovered that glass is sort of platypus-like in that it, too, can be made to combine many useful characteristics.

Take, for example, PYREX brand pipe. Here you see a man using a piece of it to drive a one-inch nail in a pine block. This is essentially an extra-curricular activity for glass pipe, which is more at home conveying metal-eating acids around chemical plants, but it's a way of showing just how tough glass can be when it's *made* that way.

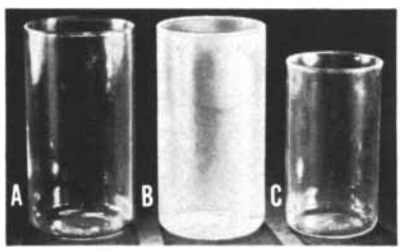


All of which may serve to illustrate for you how we can arrange the optical, chemical, thermal, mechanical, and electrical properties of glass in different combinations to match a considerable variety of end-use requirements. In fact, we've worked up some 50,000 different formulas for glass in our years of helping customers solve specific design and processing problems.

If platypus-like glass is a novel idea to you, if you've never given glass a second thought as a highly adaptable design and construction material, we suggest your reading a pocket-size volume entitled "Glass and You." It tells in a few words and many pictures how glass contributes to profit and pleasure and we'd be delighted to send you a copy. Or, if you're more concerned with putting glass to work for you than in learning what it's doing for others, there's a slightly more technical bulletin called, "Glass—its increasing importance in product design." We'll be glad to send you either—or both.

Most remarkable glass

In 1952 Philadelphia's Franklin Institute presented the John Price Wetherill Medal to Corning's Dr. Martin E. Nordberg and Harrison P. Hood for inventing the most fabulous of glasses—VYCOR brand 96 per cent silica glasses.



Evolution of a VYCOR jar: A—formed by conventional glass blowing; B—"thirsty glass"; C—finished product.

These two scientists discovered a composition that appeared to be a combination of two distinct types of glasses. One type could be dissolved out, leaving a skeleton of 96 per cent or more of silica filled with so many millions of holes that a one-inch cube contained some 60,000 square feet of hole surface.

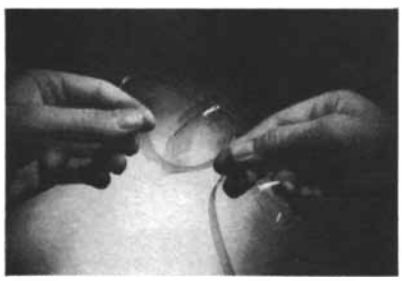
This new child of research was dubbed "thirsty glass" because, just sitting around, it absorbed moisture right out of the air. But our researchers were on the trail of something even more exciting. They heated their "thirsty glass" and it shrank to two-thirds its original size. The millions of little holes vanished and left a vacuum-tight glass that looked like any other—except that you could take this new glass white-hot from a blazing furnace and plunge it into ice water without the slightest injury. It was a glass as ideal as fused quartz, but different since it could be melted, mass produced, and worked in its original state like ordinary glass.

If you'd like to know more, just check the coupon above.

Ribbon glass by the yard

Here's a glass that's a thousandth of an inch thin and in small widths it's flexible as—well, a ribbon. You can twist it, roll it, wrap it around your arm without cracking it. It comes in any length you want—inches, yards, miles.

Actually ribbon glass isn't a single glass. We can make it of several different compositions according to what you need it for. Originally we developed it to take the place of mica in electronic capacitors of which there are several in your radio and TV sets and in any other piece of electronic equipment you can name. As mica is formed in layers, it is subject to cleavage in the plane parallel to lamination; ribbon glass being homogenous is easily workable. This is just one advantage of this glass in capacitors.



Medical scientists have found a quite different use for ribbon glass—as microscope slide covers. These are the wafer-like pieces of glass that are used to cover blood smears and the like for examination under the microscope. In this case ribbon glass can be made clearer, flatter and more free of bubbles and striae than previously made glasses.

Seems as if this unique stuff should be good for a *lot* of things, but *what* (other than electrical and laboratorial) probably lies in the laps of imaginative designers. Would you like us to send you a little strip to play with? *Customer* ideas and problems that really bring out the best in glass. So, even if what's on your mind seems unrelated to any item this page discusses, glass may still be its fulfillment. We'd like to hear from you.

CORNING GLASS WORKS

CORNING, N. Y.

Corning means research in Glass

Established 1845 **SCIENTIFIC AMERICAN** February, 1956 Volume 194 Number 2

ARTICLES

DEPARTMENTS

THE COVER

The photograph on the cover shows dried specimens of small plants which grow from crevices in the bare rock during the brief summer of the Far North (*see page 88*). The plant at the lower left, with two flowers resembling small Japanese lanterns, is alpine campion (*Lychnis alpina*). The two white flowers at bottom left center are sandwort (*Arenaria peploides*). The larger plant with round purplish leaves at lower right center is the shinleaf (*Pyrola grandiflora*). To the right of it are two specimens of chickweed (*Stellaria longipes*). At upper right are four flowers of the arctic poppy (*Papaver radicatum*). At top center is the arctic rose (*Dryas integrifolia*). Running from lower right to upper left is a stalk of alpine wire grass (*Poa alpina*). The tiny flower at left center is the saxifrage (*Saxifraga aizoides*). The plants are reproduced in their natural size.

THE ILLUSTRATIONS

Cover photograph by Paul Weller

Page	Source
32	Chon Day (*top*), F. B. Modell (*bottom*)
33	Charles Addams
34-35	Paul Weller
36	Yerkes Observatory
37	Irving Geis
38	Yerkes Observatory (*top*), Irving Geis (*bottom*)
39	Yerkes Observatory
40-41	Mount Wilson and Palomar Observatories
42-46	Eric Mose
62-64	George Eastman House
65-72	New York Public Library
77-84	Bunji Tagawa
88-91	Rutherford Platt
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94-98	Rutherford Platt
101	Rudolph Skarda
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The sheet fabricating material that turns designers' dreams into Practical Realities

Is the case, cabinet, cover or other part of your product now made of a material which leaves something to be desired in...

ECONOMY? Royalite economy entails low initial tooling costs and exact, inexpensive prototypes. Tooling may be of wood, resin or metal, depending on the production run. *It's both faster and lower in cost.*

BEAUTY? Royalite's beauty of integral colors, grained or smooth, makes *a more sales-appealing product, eliminates all finishing costs*... another economy.

STRENGTH? Royalite's exclusive compounding of thermoplastic fortified with rubber gives *unequalled wearability and impact resistance.* It may be both *rigid* and tough or *flexible* and tough, as required.

DETAIL? Royalite molds readily to *sharp detail and contour,* giving latitude to the designer.

WORKABILITY? Royalite may be sawed, machined, drilled; bolted, riveted or swedged to metal and other materials.

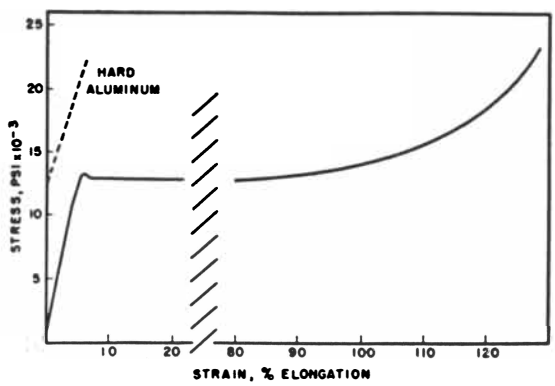
Economy? Beauty? Strength? Detail? Workability? Only Royalite has them all. Write, wire or phone for full information. United States Rubber Company, 2638 N. Pulaski Road, Chicago 39, Ill.

US RUBBER **United States Rubber**

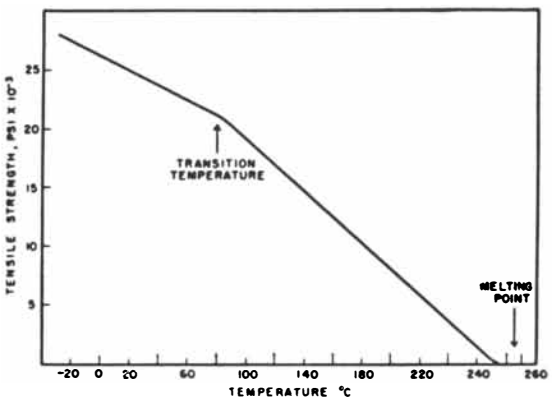
STRONGEST OF ALL PLASTIC FILMS

New Du Pont MYLAR® a wide variety of

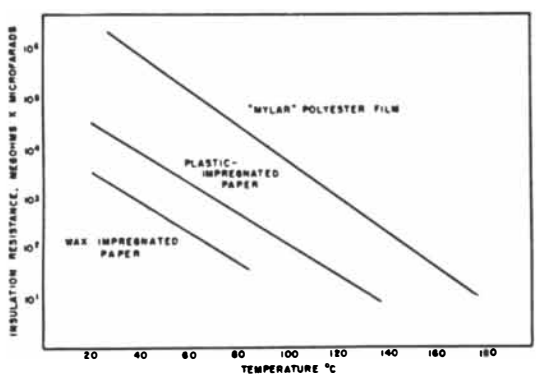
UNIQUE COMBINATION OF PROPERTIES OFFERS NEW ENGINEERING POSSIBILITIES



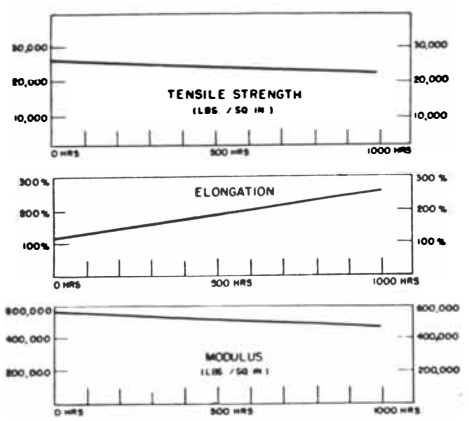
Tensile stress-strain curve for "Mylar" polyester film. This is a typical "Mylar" stress-strain curve measured at a constant rate of elongation. (100% per minute) on an Instron TT-B Tensile Tester. Yield point is comparable to that of hard aluminum.



Thermal stability of "Mylar." Above is chart showing change of tensile strength with change in temperature. One of the outstanding characteristics of "Mylar" is that its physical and mechanical properties are retained over a wide temperature range.



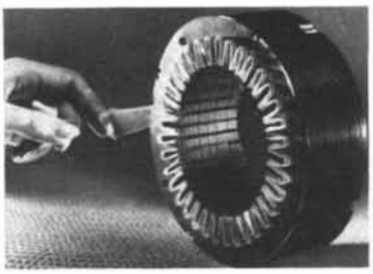
Variation of insulation resistance with temperature. Comparing this property with other commonly used commercial dielectrics reveals the outstanding insulation resistance of "Mylar" over a very wide temperature range.



Effect of heat aging at 100°C. in silicone 200 oil. These three charts show how little the properties of "Mylar" change when immersed in silicone 200 oil. This is one example of the remarkable stability of "Mylar" when exposed to many chemical reagents and solvents.

is bringing about product improvements

WIDE VARIETY OF PRACTICAL APPLICATIONS

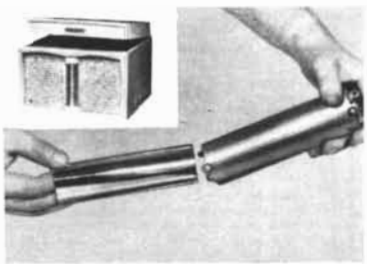


NEW Electrical Insulation

The exceptional dielectric strength of "Mylar," together with its thermal stability, chemical resistance and impact strength, make it ideal for a variety of insulating uses. Here, slot and between-coils insulation of "Mylar" makes stator winding strongly resistant to heat, moisture, aging and electrical stresses . . . increases motor life.

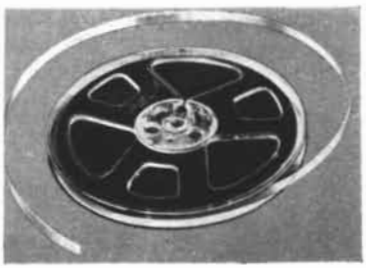
NEW Drafting Film

For precision drafting, scribing, reproduction work, this specially coated film uses "Mylar" as the base. "Mylar" is extremely tough, flexible, transparent, free from fibers, not affected by age, and dimensionally stable—insures exact register at all times. The flexible strength of "Mylar" also permits easy handling, shipping, and storing.



NEW Electrostatic Speaker

When metalized, "Mylar" is used as an electrostatic speaker for improved performance . . . undistorted sound. It provides a thin yet extremely strong diaphragm that insulates and conducts current on the same material. Fitted over a backplate, "Mylar" operates at frequencies where other diaphragms would be badly deformed.



NEW Recording Tape

Improved magnetic recording tape made with "Mylar" is being sold by leading tape manufacturers. High tensile and tear strength makes possible thinner yet stronger tapes. Exceptionally resistant to moisture and temperature extremes, the new tape lasts longer . . . is easy to store. Tape made with "Mylar" needs no plasticizer . . . won't become brittle with age.

● In a number of diversified industries, Du Pont "Mylar" polyester film is helping improve performance for a variety of products. Shown here are only a few of the many practical applications of this exciting new film.

"Mylar," with its unique balance of physical, chemical, thermal and electrical properties, may be useful to you in solving knotty development problems, improving over-all performance of existing products or helping to develop an entirely new product.

If you would like a copy of the latest booklet listing properties, applications and types of "Mylar" available, send in the coupon below.

"Mylar" is Du Pont's registered trademark for its brand of polyester film.

DU PONT
REG. U. S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING
. . . THROUGH CHEMISTRY

DU PONT ® MYLAR
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E. I. du Pont de Nemours & Co. (Inc.)
Film Dept., Room S-2, Nemours Bldg.
Wilmington 99, Delaware

Please send your latest booklet (MB-4) listing properties, applications and types of "Mylar" available.

Name _____

Firm _____

Address _____

City _____

State _____

LETTERS

Sirs:

I was amused by George Gamow's French poem in which every word represents a digit in *pi* [SCIENTIFIC AMERICAN, January]. I myself use the following free verse to recall *pi:*

How I want a drink
(Alcoholic, of course)
After the heavy lectures
Involving quantum mechanics.

Of course Gamow's device has the advantage of taking *pi* out to 30 places. Mine is only good for the first 14.

ABEL JACKSON

Brooklyn, N. Y.

Sirs:

Some of your readers may be interested in the correct version of the French poem for *pi*, yielding the correct number of letters for each digit. Here it is:

Que j'aime à faire apprendre
Un nombre utile aux sages!
Immortel Archimède, artiste,
ingénieur,
Qui de ton jugement peut priser
la valeur!
Pour moi ton problème
Eut de pareils avantages.

Not only the spelling, but also the wording of the last line was misquoted

Scientific American, February, 1956; Vol. 194. No. 2. Published monthly by Scientific American, Inc., 2 West 45th Street, New York 36, N. Y.; Gerard Piel, president; Dennis Flanagan, vice president; Donald H. Miller, Jr., vice president and treasurer.

Editorial Correspondence should be addressed to The Editors, SCIENTIFIC AMERICAN, 2 West 45th Street, New York 36, N. Y. Manuscripts are submitted at the author's risk and will not be returned unless accompanied by postage.

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A New Calculator Brings AUTOMATION Out of Blue Sky, Onto the Desk

The future is *now*. The Automation desk figuring machine is *here*. To clip hours from each day's figure work. To slash dollars from each week's overhead.

We refer to the new Monro-Matic calculator. Totally automatic, this compact single-keyboard machine actually controls itself, once you touch a key. Automation gives split-second answers to simple or complex computing problems.

Today's operators who know prefer Monroe. Vigilant executives regard Monro-Matic as a *preferred investment,* assurance against obsolescence for years to come. Monroe Calculating Machine Company, Inc. Home office: Orange, New Jersey. Branches across the nation.

Functional-Color Controls. Green control keys to multiply, red to divide. Only one of the speed exclusives that Monroe's sweeping new principle brings to figure work.

See The MAN from MONROE

for Calculating • Adding • Accounting Machines

by Gamow, resulting in wrong digits. Digits for the above have all been checked!

KURT EISEMANN

New York, N. Y.

Sirs:

I wish to call to your attention a blemish in your otherwise excellent December cover. The painting by Stanley Meltzoff shows a scrap of paper on which two differentiations have been performed. The differentiation of x^2 is written as $2\dot{x}$, $\dot{x}$ being the differential. However, the correct differentiation of x^2 should read $2\dot{x}x$.

WILLIAM H. MCDONOUGH

Cambridge, Mass.

Sirs:

There is indeed an error in the differentiations on your December cover, which was associated with my article on Newton. The error is in the second fluxion, or derivative. The fluxion of x^3 is given correctly as $3\dot{x}x^2$, but the fluxion of x^2 should be $2\dot{x}x$. While the notation of fluxions in the form of $\dot{x}$ or x^1 has been largely superseded by the Leibnitz notation dx/dt, there is one famous occasion where we still use the notations of both Newton and Leibnitz, the so-called equation of Lagrange.

I. BERNARD COHEN

Cambridge, Mass.

Sirs:

The article "A Model of the Nucleus" by E. P. Rosenbaum and myself [SCIENTIFIC AMERICAN, December] is accompanied by a photograph of the experimental setup for neutron research at Brookhaven National Laboratory. This picture may give the impression that most of the experimental work on which the article is based was done at Brookhaven. Actually only part of the work was done there. The beautiful measurements presented in the figure on page 85 were made at the University of Wisconsin by Professor Heinz Barschall and his collaborators. Those measurements are published in the following articles: *The Physical Review*, Vol. 86, p. 431 (1952); *The Physical Review*, Vol. 88, p. 83 (1952); *The Physical Review*, Vol.

Rare Earth Chloride

available in large quantities at surprisingly low cost for a wide variety of industrial uses

a report by LINDSAY

You have probably always thought that rare earths are really rare. Some of them are very rare and very, very costly.

Fortunately, however, rare earth chloride is readily available in commercial quantities (and we mean carloads) to serve a wide variety of industrial uses. It is one of the most economical sources of rare earths, some grades costing in quantity lots approximately 30¢ per pound.

Rare earth chloride is a natural mixture of hydrated rare earth chlorides produced from monazite ore. It contains chiefly the chlorides of cerium, lanthanum, neodymium, and praseodymium with smaller amounts of samarium, gadolinium, and less-common rare earth chlorides.

The rare earths are trivalent metals, and rare earth chloride is an excellent source, and an economical source, of these heavy metals. It is a water-soluble salt showing relatively little hydrolysis. Like most other rare earth salts, its basicity is generally like that of calcium salts.

* * * *

When you flick your cigarette lighter, you are using misch metal (the stuff of which lighter flints are made) and this is produced from rare earth chlorides. Misch metal itself is used as an additive in many grades of steel.

It's a versatile material, this rare earth chloride – it is used in paint and ink driers, as an anti-corrosive treatment for filter cloths, and in many other applications.

This unique material (there is nothing else quite like it) is challenging the imagination of research people in a wide variety of industries. Some see it as a possible replacement for other, higher cost materials. Others are exploring it with a view to improving production processes, enhancing product quality, and developing by-products.

Here are just a few of the many uses of rare earth chlorides. You are certain to discover others.

Caries inhibitors in tooth paste and dentifrices. Chrome plating bath additive. Silk loading. Primary cell carbon anodes. Mordant for leather and textile dyeing. Additive to baths for applying hot dip coatings to aluminum. Stypulant for embalming. Ultra-violet light absorber. Catalyst. Trace elements in fertilizer. Textile waterproofing.

You may have research projects or production processes in which rare earth chloride could be of help. To satisfy a researcher's insatiable curiosity, or to appraise its potentials in your operations, it will reward you to talk with us about rare earth chlorides. We'll be happy to send you technical data and a typical analysis.

Photos show latest addition to Lindsay monazite processing plant at West Chicago and a car being loaded with rare earth chloride for shipment to a Lindsay customer.

LINDSAY CHEMICAL COMPANY

264 ANN STREET, WEST CHICAGO, ILL.

89, p. 775 (1953); *The Physical Review*, Vol. 93, p. 461 (1954).

VICTOR F. WEISSKOPF

Cambridge, Mass.

Sirs:

Professor Gamow's article in your October issue suggests how combinations of three nucleotides may constitute a code for amino acids. However, the underlying assumption that the sequence of these nucleotides is unimportant does not appear plausible in view of the close fitting of molecular geometry required for serological and enzymatic specificity. It would seem that a reversal of the nucleotide order could be tolerated, but not, for example, a substitution of an ACA sequence for AAC. Similarly, sequences such as ACT, TAC and CTA would have to be considered as distinct. Thus, the number of significantly different combinations is increased from 20 to 40 and the suggestive analogy with the number of amino acids in proteins is lost.

H. MORAWETZ

Polytechnic Institute of Brooklyn
Brooklyn, N. Y.

Sirs:

Dr. Morawetz is quite correct in his statement that the assignment of 20 amino acids to various triplets of nucleotides is possible only if one disregards the order of the nucleotides in any given triplet. It should be kept in mind, however, that the argument for or against the importance of the order of nucleotides in the triplets depends on as yet unknown geometrical details of the RNA molecule. If, for example, an RNA molecule in the process of protein synthesis has a solenoidal shape with the repetition period of three, three neighboring nucleotides will always form an equilateral triangle, and the importance of the order of the nucleotides may become unimportant.

Thus I am inclined to consider the relation between 20 amino acids and 20 possible nucleotide triplets (disregarding the order) as a heuristical hypothesis which may or may not lead us to the better understanding of the process of protein synthesis.

G. GAMOW

Washington, D. C.

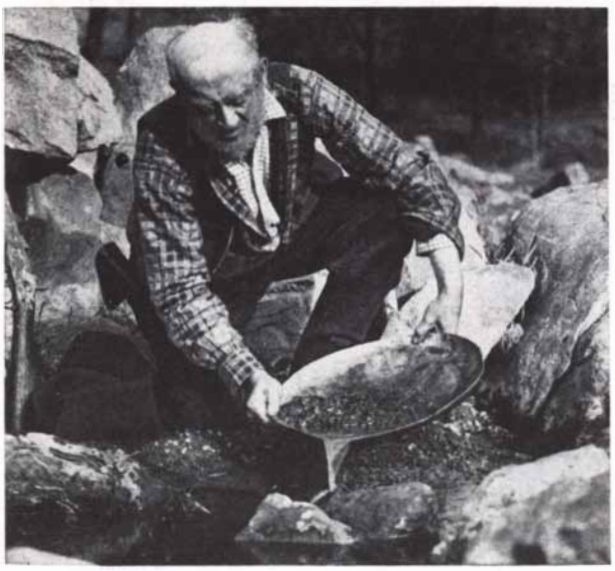
Life ...on the Chemical Newsfront

NEW PROCESS KEEPS FOOD FRESH LONGER. Years of research on the use of antibiotics to slow food spoilage now are paying off. In the photograph (right), a solution of ACRONIZE* chlortetracycline (based on a special food grade of AUREOMYCIN® chlortetracycline) is being added to chilling tanks in which processed chickens are cooled. Only 2.6 ounces in a 200-gallon tank slows growth of spoilage bacteria, lengthening poultry freshness several days. Test birds stored two and three times longer than the normal merchandising period under commercial refrigeration taste and look the same as fresh-killed fowl. Only trace amounts of the antibiotic are in the solution, and these diminish on aging, disappear entirely on cooking. This new process may soon be extended to fish and other meats to bring fresher food to your table. **(Fine Chemicals Division)** *Trade-mark

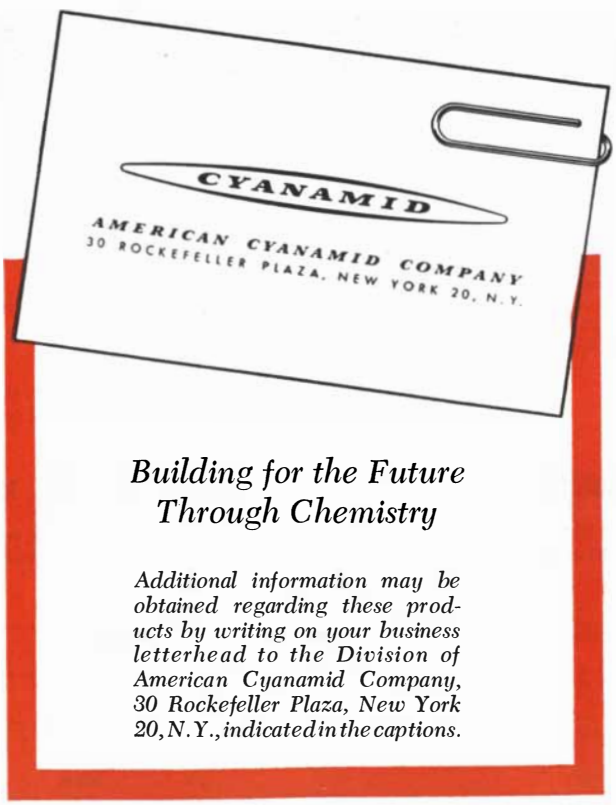
"FIRE-ENGINE RED" is the familiar name for Cyanamid toluidine toners, the pigments that produce brilliant, clean shades of red. Highly resistant to weathering, they are used extensively in finishes for fire-fighting equipment, hydrants, farm implements, gas pumps, signs and other metal or wood surfaces exposed outdoors all year long. Because of high hiding power, these pigments cover well and go a long way in paint formulations. Offered in light, dark or medium shades, they are easy to disperse in typical paint formulations. **(Pigments Division)**

A NEW CONCEPT IN INSECT CONTROL is embodied in THIMET® Systemic Insecticide. The first systemic that can be applied effectively to seeds, it is absorbed by the growing plants and kills insects that feed on them for periods up to 7 weeks. Results of a typical field test on cotton are shown above: unprotected plants on the left have been stunted by early season insect attack; plants on the right were treated with THIMET Systemic Insecticide. As a result of such tests, THIMET will be marketed on an experimental basis to cotton seed dealers in Texas and Mississippi for treatment of seeds for this year's crop. **(Agricultural Chemicals Division)**

MODERN TORTURE CHAMBER FOR DYES is the family washing machine. High water temperatures, strong detergents, bleach and constant agitation soon separate color from fabric—unless dyes are truly fast. Best dyes chemistry has yet developed for cottons, washable rayons and linens are Vat Dyes. Chemically fixed in the fabric for its life, they take all the washing, exposure to sun, salt water, perspiration and rubbing the fabric itself can stand. Cyanamid Vat Dyes, of course, are only part of a full line of dyes used in textile, paper, leather, plastics and other products where color counts. **(Organic Chemicals Division)**



LET'S GO PROSPECTING IN A *MODERN* WAY. Our New Product Development Department does everything it can to help chemists prospect the commercial possibilities of new chemicals developed by our research laboratories. One such chemical is N,N'-METHYLENEBISACRYLAMIDE, a reactive, bi-functional monomer that undergoes reactions typical of activated double bonds or amide groups. It copolymerizes with other monomers in the presence of peroxide catalysts to yield cross-linked, insoluble resins. Another important property of N,N'-METHYLENEBISACRYLAMIDE is its ability to react with compounds containing active hydrogens. Similar applications of this monomer may lead to pay dirt in your particular field. If prospects look good to you, let us send you data and a sample. **(New Product Development Department, Section A)**



50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

FEBRUARY, 1906: "A series of experiments to investigate by means of kites the relationship between the circulation of the upper and the lower strata of the atmosphere, in order to know what winds to expect, are to be carried out by the British Meteorological Society. An experimental station is to be established in England, but the researches are to be international in character, for on certain days kites will be sent up simultaneously in England, France, Germany, and Russia. Mr. W. H. Dines, F. R. S., will superintend the experiments, and he will be assisted by Col. Capper of the military balloon section at Aldershot, and Capt. Simpson of the steamship *Moravian*, during his passages between Plymouth and Australia. The vessel will be provided with suitable kites, wire, winch, and the ingenious meteorograph, the invention of Mr. W. H. Dines, who has carried out important work in this branch of meteorological investigation on a government vessel off the west coast of Scotland. In these researches a string of kites was used, the largest of which was 12 feet high, with an area of 156 feet, and a weight of 20 pounds. The kites were flown on steel wire hawsers attached to a winch wound by steam. A height of 10,000 feet was reached and recorded."

"The British Admiralty intend to test wireless telegraphic communication between battleships in the forthcoming maneuvers. The tests are to be carried out to ascertain the ability of British vessels, with their existing apparatus, to intercept wireless signals transmitted between opposing vessels, and to what extent their apparatus can be adapted when their signals are being intercepted. In the preliminary operations one fleet will start from the coast of Spain and the other from the West African coast. Each will operate in divisions at about forty miles apart."

"Prof. Küstner, Director of the Bonn Observatory, has recently determined the speed of revolution of the earth on a

Experimental model of Bell's new high-frequency transistor. It has a cut-off frequency of at least 500 mc and can be used to amplify 2500 independent voices simultaneously.

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that smashed a frequency barrier

A new transistor invented at Bell Telephone Laboratories can provide broadband, high-frequency amplification never before possible with transistors. The big leap in frequency is made possible by a diffusion process that earlier enabled Laboratories scientists to create the Bell Solar Battery.

This transistor is a 3-layer semiconductor "sandwich." High-frequency operation is obtained by making the central layer exceedingly thin. This was difficult to do economically by any known method.

The new diffusion process, however, easily produces microscopic layers of controllable thickness. Thus it opens the way to the broad application of high-frequency transistors for use in telephony, FM, TV, guided missiles, electronic brains and computers.

The new transistor shows once again how Bell Laboratories creates significant advances and then develops them into ever more useful tools for telephony and the nation.

A Bell scientist checks temperature as arsenic vapor diffuses into germanium, creating 4/100,000-in. layer.

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spectrographical method, from the periodical displacement observed in the lines of Arcturus. From June 24, 1904, to January 15, 1905, as many as eighteen suitable photographic plates were obtained, all of which had been exposed an hour after the star referred to had traversed the meridian, *i.e.*, shortly after dusk in summer and shortly before dawn in winter. Special precautions had to be used in obtaining the arc spectrum of iron which was to serve for comparison. Sixteen lines of iron were chosen. The spectrographic lines were measured on each of the plates under the microscope. Disturbances were caused by the moon's revolution round the earth, and even the disturbance produced on the sun by the powerful planet Jupiter had to be considered in order to obtain really accurate results. What is called the constant of the earth's speed of revolution was eventually obtained at 29.617 kilometers per second, with a probable error of ± 0.057 kilometer."

"The German Army, which already has three battalions of telegraph operators and one of aeronauts, is to be provided in the near future with a volunteer corps of chauffeurs. The corps is to be recruited from among the members of the German Automobile Club and it is limited to the Prussian provinces and the states whose military contingent is under the direction of the Berlin authorities. The persons who wish to enter as volunteers are asked to apply to the Automobile Club, with a declaration according to which they engage to undertake three periods of maneuvers of ten days each, in the space of four years, and to carry out all the orders which are given them by the officer in command. Prince Henry of Prussia has been placed at the head of the corps."

SCIENTIFIC AMERICAN

FEBRUARY, 1856: "The United States now has more miles of railroad in operation than all other countries put together. The total length of our railroads is 19,664 miles. In 1848 there were only 5,682 miles of railroad in our country; consequently 13,982 miles have been built during the last seven years. This is a most astonishing increase, being nearly double those that were built during the previous twenty years. Great Britain and Ireland have only 8,500 miles in operation, while those on the

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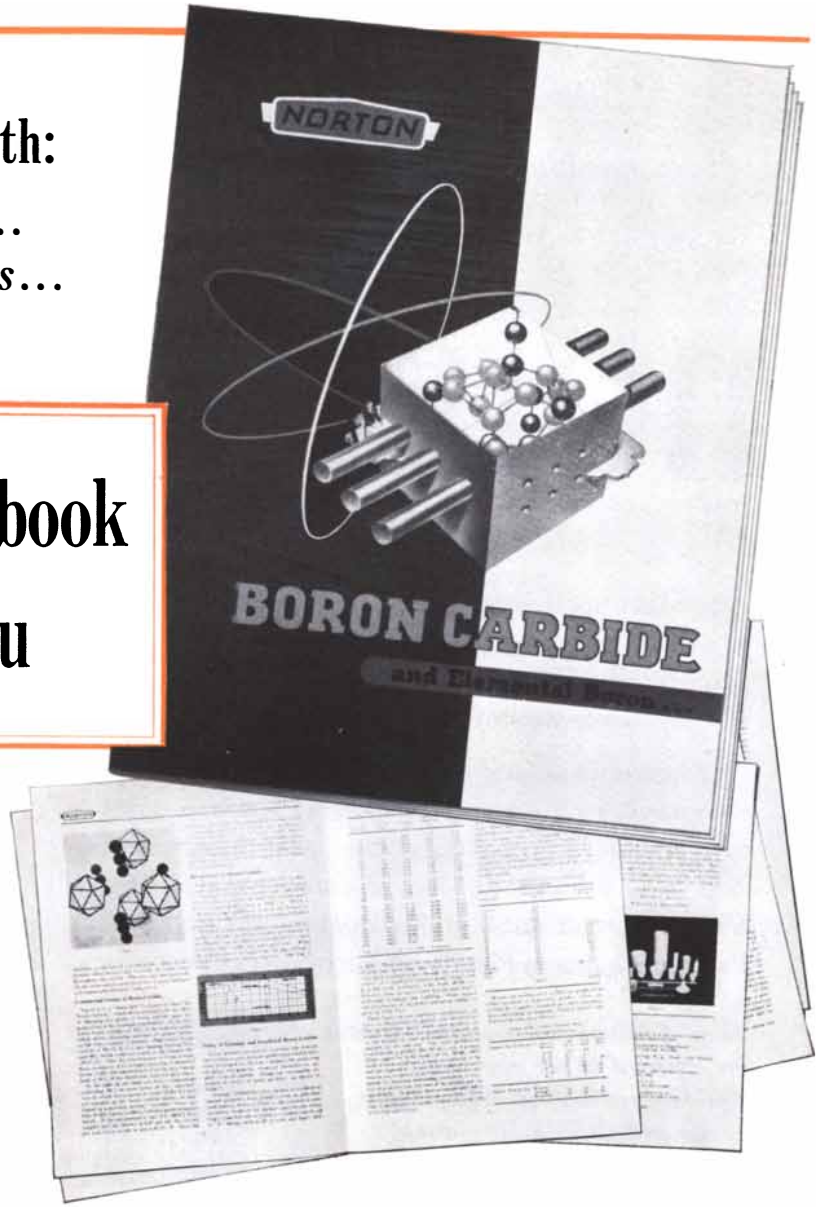

This new free Norton *"Handbook on Boron Carbide and Elemental Boron"*, is a valuable reference, containing both fundamental data and practical information. Printed in colors with many charts and tables it will serve as a useful and permanent addition to the reference files of those concerned with atomic energy and related fields.

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continent of Europe do not amount to 6,000 miles."

"N. K. Wade of Pittsburg, Pa., has gone to Russia, in the Emperor's employ, to superintend the manufacture of cannon at St. Petersburgh. He is to receive $5,000 per annum."

"M. Bernard, a French chemist, has, it is said, demonstrated by several experiments that the white of eggs can only be assimilated or converted into food for the human body through the intervention of the liver. Guided by this fact, Dr. Giesler, of Goettingen, has suggested its employment in the treatment of jaundice. If the digestion of the albumen of eggs tends to rouse the action of the liver, it will necessarily restore the secretion of bile and cure jaundice."

"The New Jersey Geological Report shows that the Atlantic is steadily, and rather rapidly, encroaching upon the land on its coast. At Cape Island the surf has eaten inwards full a mile since the Revolution. Along the Bay Shore in Cape May the marsh wears away at the rate of a rod in two years. One of the beaches upon the coast is mentioned as having moved inward one hundred yards in the last twenty years. It is also the opinion of the oldest observers that the tides rise higher upon the eastern New Jersey uplands than formerly. Prof. Cook, of the Geological Survey, is confident that the shore is now settling at the rate of about two feet in a hundred years."

"The most difficult part of Mr. H. K. Brown's great bronze equestrian statue of Washington, namely, the entire body of the horse, has just been cast at Ames Foundry, in Chicopee, Mass. The Springfield *Republican* says that about one hundred persons had gathered from neighboring shops to witness the scene. Soon after the hot metal began to flow into the mold it commenced spirting with great rapidity from every crevice in the mold, and in all directions. The workmen who stood upon and around it were enveloped in a shower of liquid fire, which burned their hands and faces, and set fire to their garments, while the spectators fled in terror from the building. The foreman of the shop, Mr. Langdon, anticipating some trouble, had agreed with his workmen not to give up the object of their long endeavors if a desperate effort could save it. With courage that deserves great praise, they persevered and filled the mold, escaping with only slight injuries."

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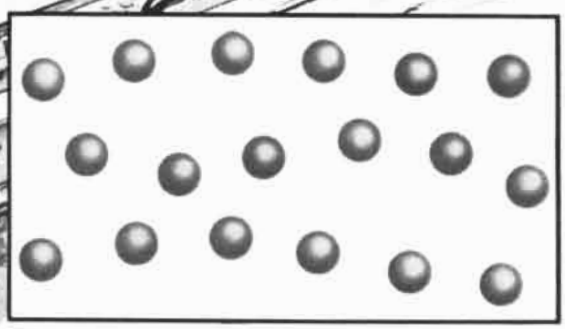
The adhesive-making



Unvulcanized rubber is essentially a plastic substance. Since its molecules are not tightly linked together, it will permanently deform when stretched. An adhesive made from uncured rubber cannot produce a high-strength bond.

secret that isn't in any formula

There's nothing in the formula for an industrial adhesive that tells you anything about the subtle art of putting the ingredients together. Nevertheless, this secret often is the most important single factor in producing an outstanding adhesive. In fact, it's so important that in many cases the formula could be given to a competitor . . . and he might never be able to duplicate the compound.

There are many facets to the art of making adhesives. One of them is as simple and basic as the size of the batch you mix. An adhesive made in an experimental laboratory usually has different properties when it's produced on a large scale. Achieving laboratory quality in production quantities takes skill not found in any formula.

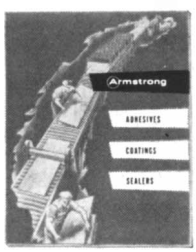
Another thing an adhesive formula doesn't tell you is the order in which ingredients should be mixed. For example, Armstrong chemists know that certain adhesives can be made far stronger by doing just two things: by combining the raw materials in a particular order; and by a delicate adjustment in their proportion.

Advanced processing techniques can also be used to extend the natural limits of some raw materials. As an illustration of this, Armstrong research chemists were recently given the problem of building more "muscle" into an already successful rubber-base adhesive.

The immediate answer seemed to be vulcanization, since it's well known that this process strengthens rubber. There was a catch here, though. Fully vulcanized rubber can't be dissolved in the solvents normally used in making adhesives. A partially vulcanized rubber could be dissolved all right, but vulcanization is a process that's hard to stop at exactly the same point every time. It would be practically impossible, therefore, to keep the quality of the adhesive uniform from batch to batch.

Armstrong chemists solved the problem by combining two rubbers that are cured with different agents. Then they treated the blend so that only one rubber cured—and its strength reinforced the uncured rubber. The result: an adhesive that was plastic and workable —and had far greater strength than its predecessor.

Making new and better adhesives is a year-round job at Armstrong. Because of this, we've been able to help a lot of fabricators find better ways to join things. For helpful information on how you can use adhesives, send for our new 36-page illustrated manual, "Adhesives, Coatings and Sealers." It's free to industrial users. Write on your letterhead to Armstrong Cork Company, Industrial Division, 8202 Inland Road, Lancaster, Pennsylvania.



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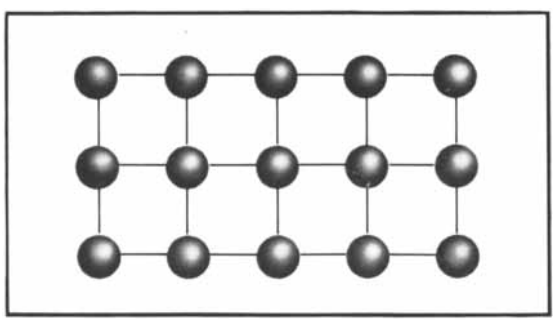
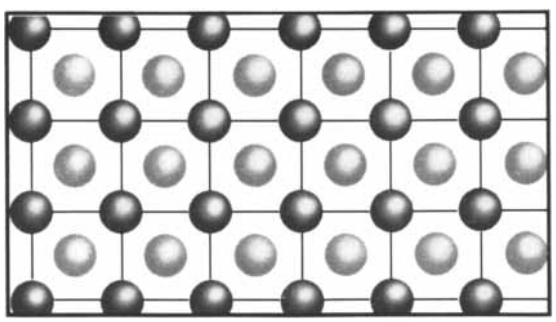


Fully cured rubber, on the other hand, is elastic. Because of its tightly linked molecules, it will return to its original shape after being stretched. But a fully cured rubber can't be dissolved in the solvents used to make an adhesive.



A combination of these cured and uncured rubbers does the trick. The particles of the cured rubber lend strength and elasticity to the uncured rubber. These blended rubbers can be dissolved to make a high-strength adhesive.

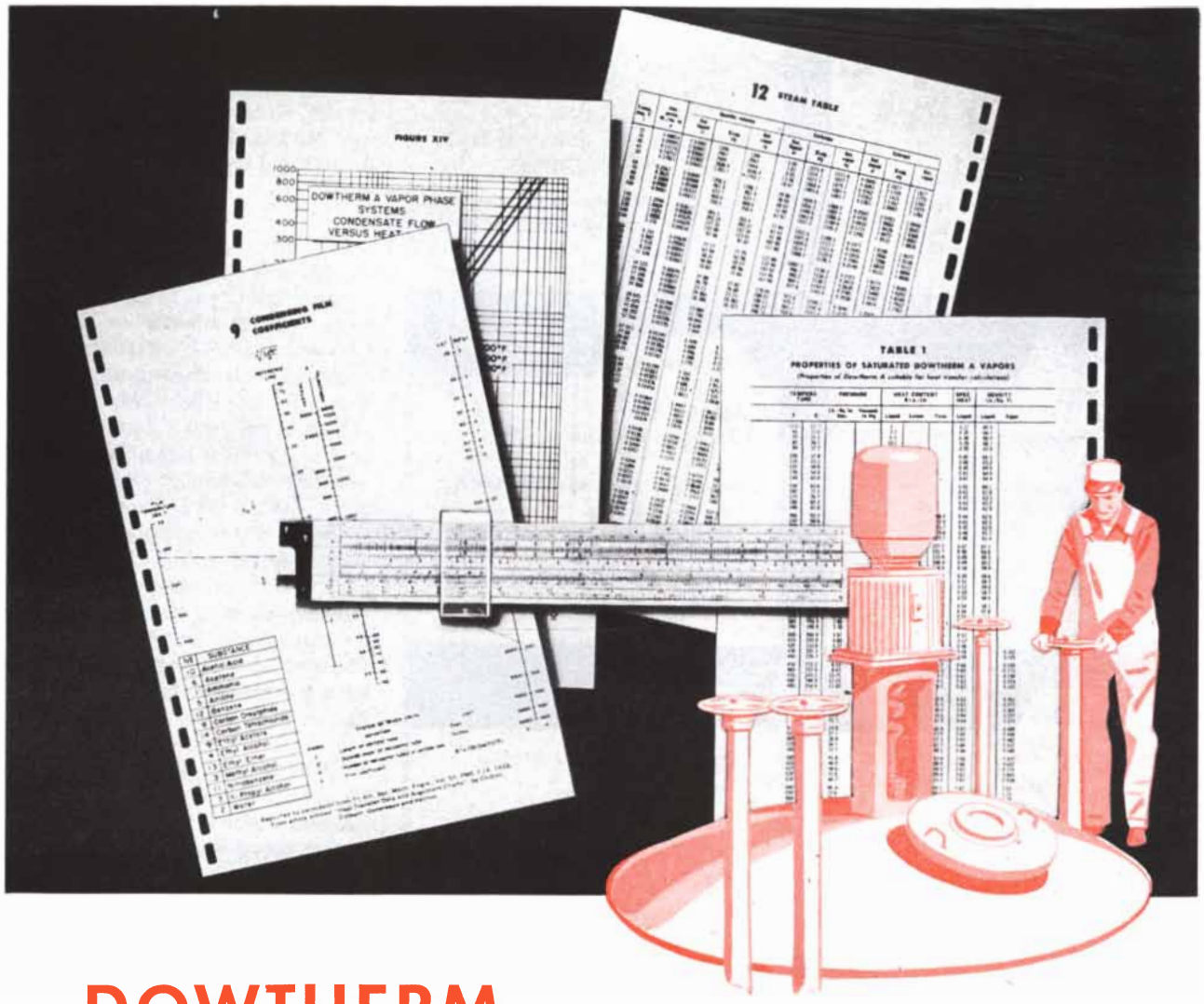
THE AUTHORS

JACOB LEVINE ("Responses to Humor") is associate professor of clinical psychology at Yale University and chief psychologist of the Veterans Administration Hospital in West Haven, Conn. As a newsboy in Boston he won a scholarship which enabled him to go to Clark University to study psychology, and he graduated in 1936 with honors. He did his graduate work at Harvard University, and for several years was research assistant to the neuropsychologist Karl S. Lashley. He writes that at this time he "did a lot of research on brain functions and vision, especially in birds. Demonstrated that birds have what seem to be two independent visual systems: that is, when they are taught something with one eye, they do not retain the habit when tested with the other eye." For three years he was chief consulting psychologist to the U. S. Army Rehabilitation Center for Blinded Soldiers in Avon, Conn. Here he did research on so-called facial vision. He has taught at Yale since 1948. He is investigating humor on a grant from the Foundations Fund for Psychiatric Research.

ADRIAAN BLAAUW ("Young Stars") is a member of a constellation of Dutch astronomers who have moved in recent decades from the Netherlands to the U. S. Born in a suburb of Amsterdam in 1914, he was drawn to astronomy in his high-school days under the influence of an inspiring teacher. After studying at the University of Leiden he took his Ph.D. at the University of Groningen in 1946, then returned to Leiden, where he later became a reader in astronomy at the observatory. During these years he spent four months on a Leiden observatory expedition to Kenya in central Africa and twice came to the U. S., each time for a half-year of research at the Yerkes Observatory of the University of Chicago. In 1953 the University of Chicago appointed him associate professor of astronomy, and he has been there since. Most of his work has been on the structure of the Milky Way and of other stellar systems—"a subject to which important contributions have been made by the Dutch school of astronomers since Jacobus Kapteyn"—but it is the evolution of stellar systems that interests him most at present.

A. M. GUHL ("The Social Order of Chickens") is a Kansas State College

The modern concept in process heating



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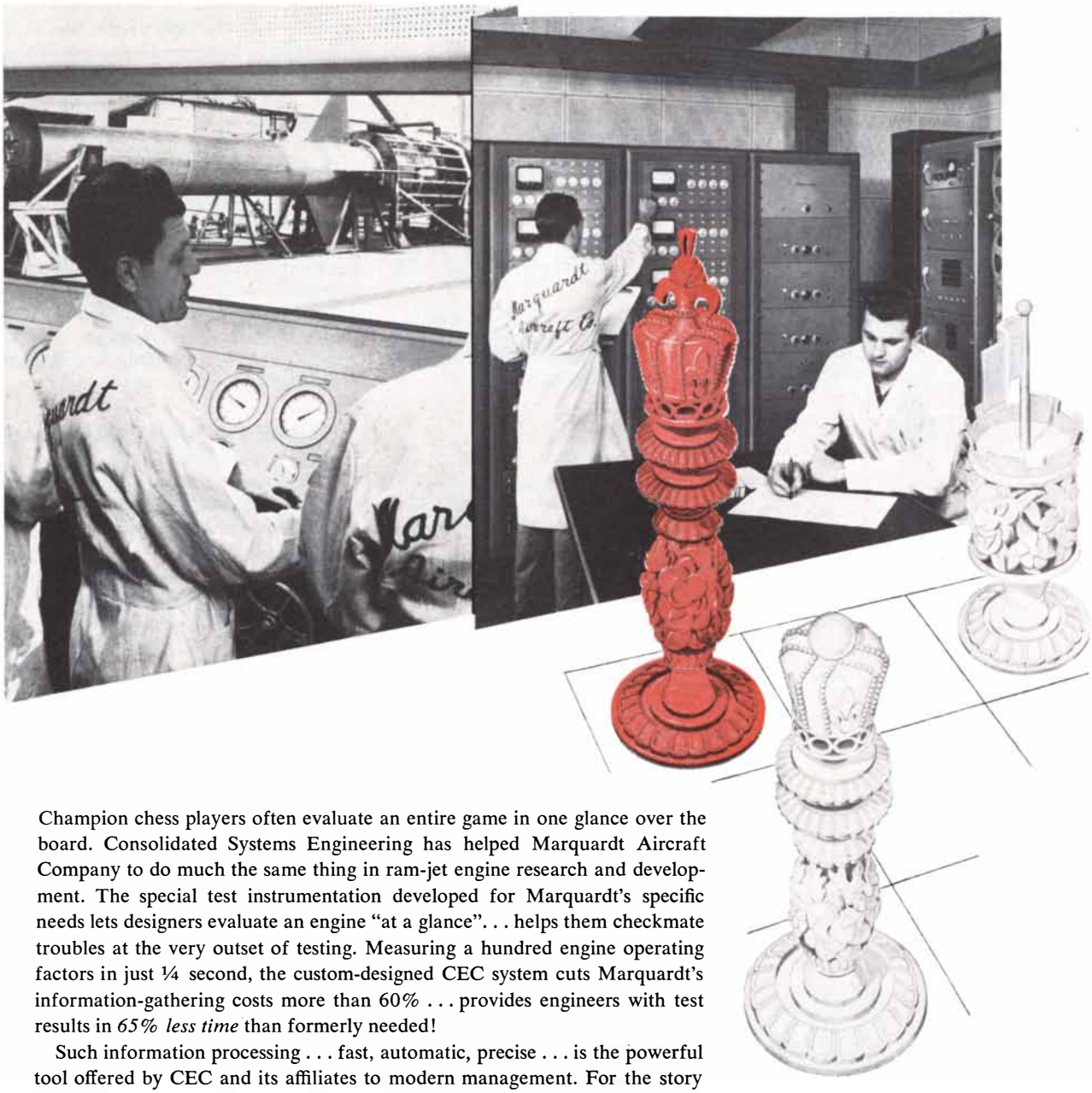
zoologist who has specialized in the behavior of chickens. He attended North Central College in Illinois, taught school for several years, then went to the University of Chicago, where he took a Ph.D. in 1943. He was interested in the endocrine glands of birds and was studying the comparative anatomy of hawks and owls. At about that time the University of Chicago zoologist W. C. Allee and his students began working on the social behavior of chickens and other vertebrates, and "for some unexplainable reason," Guhl says, "this field fascinated me." He joined the Kansas State faculty in 1943 and was appointed professor in 1950.

LOREN C. EISELEY ("Charles Darwin") is professor of anthropology at the University of Pennsylvania. He is a frequent contributor to SCIENTIFIC AMERICAN. When his activities were last reviewed in this department in connection with his article "Man the Fire-Maker" in the issue of September, 1954, he had just been commissioned by the American Philosophical Society to compile a bibliography of Darwin. He is still at work on this project, which entails assembling material on evolution to shed light on the correspondence between Darwin and Sir Charles Lyell, which the Philosophical Society has purchased. Eiseley is also writing a history of evolutionary thought for the Doubleday Anchor Book series.

RICHARD C. PINKERTON ("Information Theory and Melody") is an assistant research professor of chemical engineering at the University of Florida. He lays no claim to musical expertness, apart from being "a veteran of many serenadings of the women's dorms." He graduated from Michigan State College in 1945 and in 1951 took his Ph.D. at Iowa State College, where he remembers spending a good deal of time taking courses in mathematics at the expense of his work in chemistry. "My field of specialization," he writes, "has been thermodynamics and chemical kinetics, but I have tried to avoid being classified as the practitioner of any one branch of science. I believe that the areas between the formal, organized fields of study need more attention."

RUTHERFORD PLATT ("Flowers in the Arctic") is a New York businessman whose botanical hobby has carried him on two expeditions to the Arctic. He heads the advertising agency of Platt, Dyson and O'Donnell. His interest in trees and flowers dates from the early

How to checkmate design problems



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1930s, when he started studying them at the Brooklyn Botanic Garden. Before going on the 1947 MacMillan expedition to northern Greenland, he studied boreal plants with the help of the late M. L. Fernald in the Gray Herbarium at Harvard University. From the 1947 expedition he brought back hundreds of pressed specimens for the herbarium of the New York Botanical Garden. He returned to the Polar regions in 1954 to collect and photograph plants. Platt is a trustee of the Brooklyn Academy of Arts and Sciences and a member of the governing committee of the Brooklyn Botanic Garden. In 1953 he was natural-history adviser to the Walt Disney True-Life Adventure productions. For his book *This Green World* he won the John Burroughs award in 1945.

ROBERT B. AIRD ("Barriers in the Brain") is chairman of the department of neurology at the University of California School of Medicine in San Francisco. He was born in Provo, Utah; his father was a doctor. After graduation from Cornell University in 1926 he attended the Harvard Medical School, where he took an M.D. in 1930 and where his interests turned to neurology. He interned at Strong Memorial Hospital in Rochester, N. Y., and in 1932 joined the University of California School of Medicine, becoming professor of neurology and neurosurgery in 1949. Aird's nonmedical interests turn to the outdoors and to music. He likes to take pack trips into out-of-the-way mountainous areas in California and Utah and has done some mountain climbing. He is also an amateur pianist and composer.

JAMES B. KELLEY ("Heat, Cold and Clothing") is a physicist who has had a diversified career. He was born in New York, graduated from Marquette University in Wisconsin in 1937 and returned to New York to become chairman of the chemistry department of a high school. In 1941 he took an M.S. in applied mathematics and physics at New York University, then went with the Sperry Gyroscope Company as an assistant project engineer for a year. He returned to teaching, successively at the College of the City of New York, the U. S. Naval Postgraduate School and Hofstra College. He studied aeronautical engineering at N. Y. U. and received a Ph.D. In 1952 he became president and director of research of Physics Research Laboratories. He has temporarily left this last job to act as consultant on industrial research to the Commissioner of Commerce of New York State.

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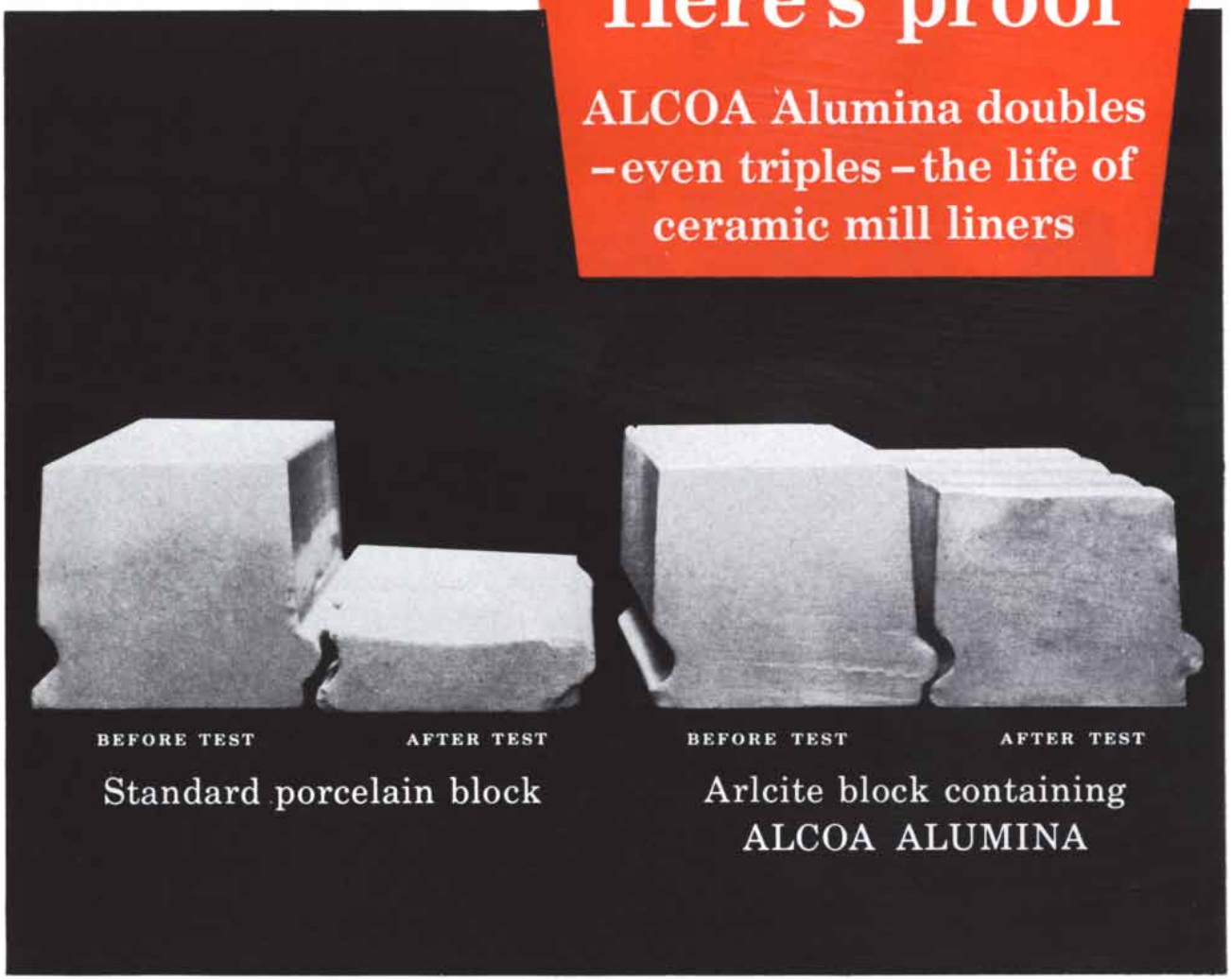

The first and third blocks from the left, shown above, were used to line a mill in which accelerated grinding tests were conducted. The same blocks, after test, are beside the originals. Note how abrasive action in grinding has seriously worn away the standard porcelain, yet has had little effect on the Arlcite block. Arlcite, manufactured by **The Patterson Foundry & Machine Company,** East Liverpool, Ohio, is a high density ceramic, the principal ingredient of which is ALCOA Alumina.

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Responses to Humor

On the Freudian theory people laugh when they momentarily gratify a forbidden impulse. This view is now applied in a psychological test based on the reactions of the subject to a series of humorous cartoons

by Jacob Levine

The enormous amounts of money and effort spent in the pursuit of laughter testify, if any testimony were needed, to the fact that the desire to laugh is a basic human craving. Yet for some reason few persons have tried to investigate this area of behavior scientifically. Perhaps the reason is merely the one that occurs to the conscious mind: that humor seems too elusive and too frivolous a subject to be studied seriously. But it is also arguable that part of the reason for the resistance to analyzing humor and laughter lies much deeper.

Thomas Hobbes once shrewdly remarked: "The passion of laughter is nothing but sudden glory arising in ourselves from sudden conception of some eminency in ourselves by comparison with the inferiority of others or with our own formerly." Immanuel Kant defined humor more succinctly as "an affection arising from a strained expectation being suddenly reduced to nothing." Kant's definition is close to being a capsule summary of the theory of humor later worked out by Sigmund Freud. The psychoanalyst's interpretation of humor not only appears to make sense but has afforded a basis for exploring both the meaning of laughter and the subconscious area of human psychology.

Freud's theory, simply stated, says that humor gives pleasure by permitting the momentary gratification of some hidden and forbidden wish and at the same time reducing the anxiety that normally inhibits the fulfillment of the wish. By making light of the forbidden impulse, treating it as trivial or universal, a joke or cartoon releases inner tension. The sudden release of tension comes as a pleasant surprise, while the unconscious source of the individual's tension is so disguised in the joke that it is usually not disturbing.

Consider, for example, a cartoon portraying a man who, while watering his lawn with a garden hose, turns to look at a pretty girl in shorts walking by and in doing so sprays his wife, who is sitting on the porch. Most men will laugh at this "accident" because it dramatizes in innocent form a common secret dissatisfaction and desire to philander. Women, understandably, tend to see nothing funny in this type of cartoon; too often they find themselves close to the role of the sprayed wife.

Sex and aggression are the main themes of humor because they are the primary sources of most human conflicts and tensions. It follows that a basic element in all humor is anxiety. The anxiety arises from inner conflicts over the inhibition of strong drives or impulses. A joke seems funny only if it arouses anxiety and at the same time relieves it. From this theory we can derive a hypothesis that there are three types of reaction to a joke or humorous happening. If it evokes no anxiety at all in an individual, either because he has no conflict over the subject or because his conflict is too deeply repressed, he will be indifferent to the joke. If the situation calls forth anxiety and immediately dispels it, the individual will find it funny. But if it arouses anxiety without dissipating it, he will react to the ostensibly humorous situation with disgust, shame, embarrassment or horror.

The writer has tested the responses of several hundred persons—normal subjects and psychiatric patients—to cartoons taken from magazines such as *The New Yorker* and *The Saturday Evening Post*. In collaboration with Frederick C. Redlich of the Yale University School of Medicine he has been making studies of humor since 1948.

Age, sex, culture and other general factors naturally condition reactions to humor; we have found indications, for instance, that the older one gets, the less he appreciates jokes with a sexual theme. But the common notion that nations or classes of people differ greatly in their sense of humor is an exaggeration. The basic themes of humor are the same everywhere. The significant differences are between individuals, and they reflect deep-seated aspects of personality and emotional development.

To illustrate differences in individual response, let us consider a few examples. A cartoon by F. B. Modell shows a bearded sheik and a fat eunuch looking at a veiled woman; the sheik, in a cloud representing his thoughts, pictures her naked, while the eunuch's cloud is empty. When this cartoon was shown to an

attractive young woman who had been brought up in a rather strict home, she responded with an embarrassed smile: "Men always undress you in their mind, but I guess it's natural and I don't mind too much. In fact, I guess I like it because it makes me feel attractive." In contrast, a spinster of 45 with a puritanical attitude toward sex and hostile feelings toward men found the cartoon revolting. She exclaimed: "Men always have sex on their mind. That's just the way they think about women." A third woman, a young schizophrenic, reacted more violently. She became highly excited and cried: "I feel just like the naked woman when men look at me." This woman had delusions that her brother was forcing her into prostitution, resulting from unbearable sexual feelings she had toward him and other men.

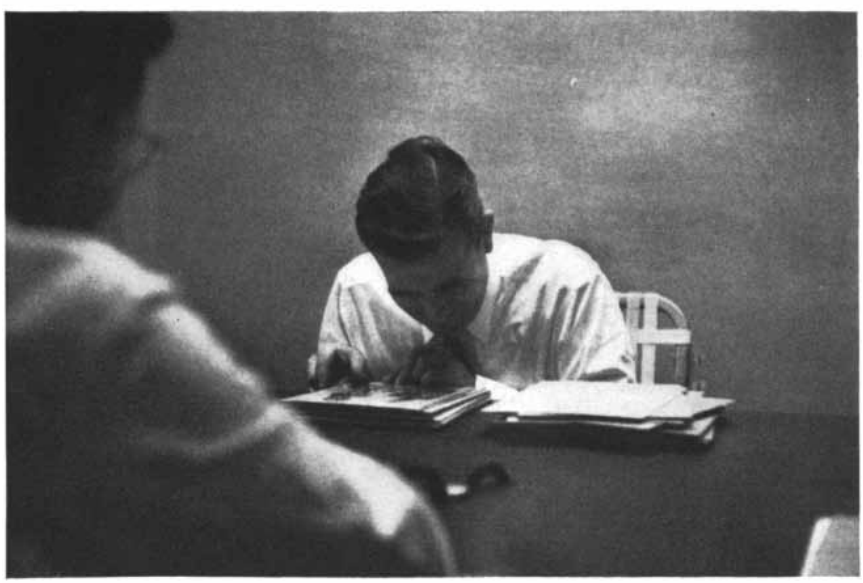
Let us take a Charles Addams cartoon showing his famous macabre family standing on the roof of their spooky Victorian house and pouring boiling oil on Christmas carolers singing below. An openly aggressive young woman found this cartoon particularly delightful. She had been brought up in a strictly religious home; now she was antireligious, and for her the cartoon represented emancipation from the repression of her youth. On the other hand, a young man of 28 found the same cartoon pointless and disgusting. He had left his church, in which he had been extremely active, and the cartoon brought out his conflict and his feeling of guilt.

Neurotic persons often read into a cartoon something quite different from what the humorist intended. An Addams cartoon depicting a man who has tied his wife to a tree and is calmly raking a pile of leaves around her, presumably preparatory to building a fire, was shown to a young woman suffering from what is called an anxiety neurosis. She said: "I don't see anything funny in it. I know what's going to happen. He is going to burn up the man with the leaves." She had unconsciously changed the sex of the victim. The young woman was in great fear of her husband; he had virtually raped her before their marriage and their marital sexual relationship seemed to her to consist in lustful attacks upon her by her husband. The cartoon was so close to some of her fantasies of revenge that she substituted her husband for the victim and found the situation too terrifying to be humorous.

Sometimes the subject's reaction may go so far as to blind him completely to a conspicuous feature carrying the

MIRTH RESPONSE TEST developed by the author and his colleagues utilizes a set of 20 cartoons. Three of them from *The New Yorker* are reproduced here. They were drawn by

Chon Day (*upper left*), F. B. Modell (*lower left*) and Charles Addams (*right*). In the test the response of the subject is recorded by the examiner on the following six-category "mirth spectrum": negative response, no response, half-smile, smile, chuckle and laugh.



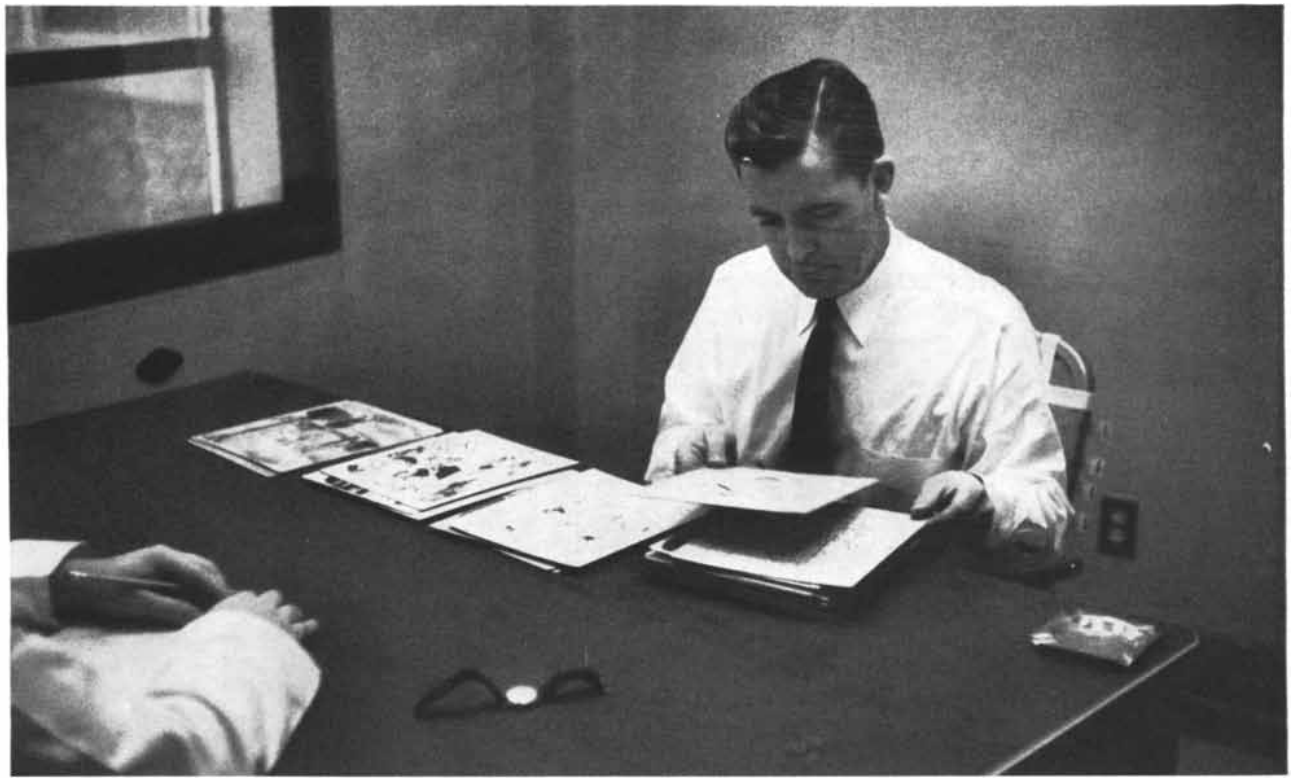
SUBJECT IS TESTED at the Veterans Administration Hospital in West Haven, Conn. In the photograph at the top he exhibits a negative response to one cartoon of the set; in the middle he laughs at another cartoon; at the bottom he doubles over with laughter at a third.

point of the cartoon. One in which an executive finds at the office suggestion box a bottle labeled "Poison" was shown to a university department head. The professor could not understand the cartoon. Not until the examiner pointed it out did he see the prominent label on the bottle. Even after he got the point—the anonymous suggestion that the boss take poison—the professor found it totally humorless. A possible explanation of his failure to see the humor emerged on further examination. The jest, it appeared, was a too-painful reminder of his worries as a department head. Playing a dual role as paternal figure and administrator, he had fears that he was either too hostile or too lenient toward his subordinates, and he was in unhappy uncertainty about whether his students respected or despised him.

More flagrant was the oversight of an aggressive professional woman who looked at a cartoon by James Thurber. It is a simple drawing of a very small and frightened man coming home to a house which takes the form of the large, angry face of a woman waiting threateningly for his entrance. The professional woman failed to see the face, despite hints and prodding, until it was actually traced out for her. Then she was not amused but upset. This woman had extremely hostile and competitive feelings toward men which she found difficult to control, and she often expressed them by explosive outbursts of anger. Her refusal to perceive the hostile woman in the cartoon seemed to reflect her desire to avoid facing the conflict that was so distressing to her.

Psychotic patients tend to be either indifferent to cartoons or disturbed by them; when they do find one funny, they are likely to laugh uproariously at some totally irrelevant interpretation of their own. For example, a female schizophrenic was greatly amused by a cartoon of a fat man standing on a weighing machine with his back to the dial (his belly protruded too far to allow him to stand facing it). When asked why she found it funny, she explained: "The man is pregnant."

Mental patients and many relatively normal people resist laughter because it means a loss of self-control, which they fear. Ernst Kris, a psychoanalyst who has made a study of humor, observes: "Laughter overcomes and disarms us. He who laughs is defenseless. We speak of an attack of laughter, and that we become weak with laughter." The unfortunate individuals who cannot laugh



SAME SUBJECT is then asked to sort the cartoons into three piles: those he likes, those to which he is indifferent and those he dislikes. These pictures were made through a one-way mirror, so that the subject was not aware that he was being photographed.

(have "no sense of humor") are restrained, we believe, by a strong and vigilant guard against the release of unacceptable thoughts or wishes.

Play, according to psychoanalytic theory, is a way of mastering anxiety which most people develop very early in childhood. After a particularly frightening experience at the dentist's, a child is apt to go home and play dentist with a doll. The violent fantasies of the comics provide a release of aggressive impulses which the child can enjoy with impunity. And Charlie Chaplin is universally hilarious to children and adults alike because he performs his outlandish and irreverent antics imperturbably, without fear and without being hurt. He is the boy and the superman in all of us.

It is no accident that comedians are often basically sad, depressed persons. For them, humor serves as a defense against anxieties arising from their relations with people. The wish to make people laugh becomes a pervasive and consuming drive; they must have laughter and applause as an expression of love. Alone or when not performing, they are apt to be withdrawn, melancholy, preoccupied.

Needless to say, no one would pretend that the studies made so far have done much more than scratch the surface of the subtle and complex subject of humor. What makes one joke funny and another like it not funny? Why does a good joke still make us laugh even though we have heard it before? Why do we find a joke more amusing when we hear it in a crowd, or *vice versa?* There are innumerable things about the expression of humor about which we know next to nothing.

Nevertheless the "mirth response test" we have employed has proved to be a useful instrument for probing personality and bringing out emotional problems. The test has been standardized as a set of 20 cartoons, and reactions to them are rated on a scale which we call the "mirth spectrum." The scale ranges from a negative grimace to a belly-laugh, with gradations in between, including no response, a half-smile, a smile and so on. As the subject looks at each cartoon, the examiner notes his immediate reaction. Then the subject is asked to sort the cartoons into those he likes, dislikes and views with indifference. Later he is interviewed on his understanding of each cartoon and the associations it evokes in his mind. His responses are then studied in relation to what is known about his background and personality.

It is no easy matter to predict what cartoons will seem funny to a given person. But psychiatrists have found that they can predict pretty reliably which cartoons will disturb their patients. Undisguised sex (*e.g.*, Peter Arno), gruesome aggression (*e.g.*, Addams), extreme prankishness and irreverence toward accepted authority (such as the police) are most often disturbing. However, persons whose sexual problems are close to the surface of awareness are apt to laugh boisterously—too readily and too loudly—at jokes about sex.

An old folk-saying has it that "to laugh is to be healthy." Someone once put it a little more specifically: "Wit gives freedom and freedom gives wit." Humor serves as a tension-releaser for most people. The more sorely troubled, who cannot relax in this way, may seek release in alcohol or pathological flights from reality. The capacity to laugh is a measure of one's adjustment to his environment. It follows that inability to appreciate humor, or deviant responses to it, can be regarded as a sensitive indicator of maladjustment and inner disturbance. Humor deserves a great deal more study, for it could become a powerful tool of psychiatry.

Young Stars

The hottest and most massive stars often occur in loose associations. If their movements are traced backward, it is found that some of them must have been born since the first mammals appeared on the earth

by Adriaan Blaauw

Our skies have many a young new star.
—Katharine Tynan Hinkson

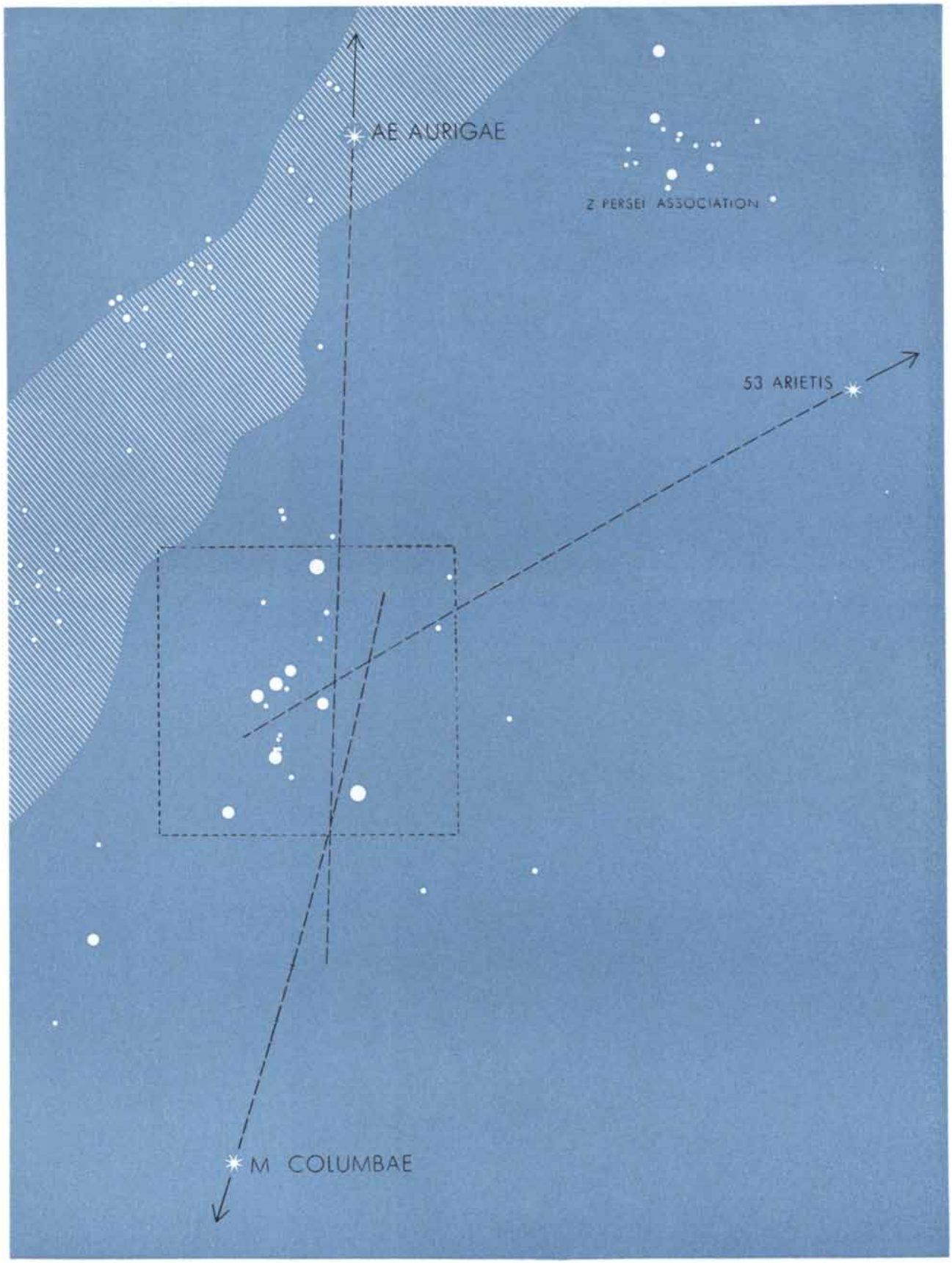
For about a decade astronomers have been searching the heavens in a fascinating quest for the birth of new stars. The notion that stars are still being born in our universe is revolutionary and startling, but the evidence already is strong and it is growing stronger. It has been established that the stars in the skies are, like living beings, of widely varying ages. Many infant stars have been identified, and we are even able to study the scene of their birth.

In the past quarter century physical studies of the "ageless" stars have opened a completely new view of their life history. Investigations of their spectra and of nuclear processes have told astrophysicists a great deal about the stars' composition and structure and about how they generate the energy that makes them shine. We now know that our own galaxy, the Milky Way, contains an immensely varied population of stars which differ greatly in size, density and brightness: some are as much as 100,000 times brighter than the sun. On the basis of what we know about their fuel supply and the rate at which they are burning the fuel, we can be certain that some of the brightest stars in our galaxy cannot have lived for more than a few million years. There is every indication that the stars of our galaxy are of all ages from one or two million to about five billion years. Between the oldest and the youngest stars the age difference is as great as that between a man 100 years old and a baby of two weeks.

ORION ASSOCIATION contains many hot, massive stars and luminous clouds of gas. The three bright stars at left center in this photograph form the familiar belt of Orion. Below them is the glowing nebula, a gas cloud in which new stars may even now be forming.

We shall consider here the youngest stars and certain significant discoveries about their association in groups. The best known of these infants are the so-called O- and B-type stars. They are the hottest and most massive stars in our system—and also rare. More than 40 years ago astronomers noted that the O and B stars were not distributed generally through the galaxy but tended to occur in groups—what are now called O-associations. These associations are not like star clusters: they are much less compact than clusters. The hot stars in some associations are spread out over a region hundreds of light-years in diameter. All of the O-associations lie out along the spiral arms of our galaxy. In each association the hot young stars are embedded in a general population of other stars and great clouds of interstellar gas.

Several years ago a Soviet astronomer, V. A. Ambartzumian, revived interest in these associations by pointing out



FUGITIVES FROM ORION, the stars AE Aurigae, M (Mu) Columbae and 53 Arietis were probably born in this association, but are now moving away from it at high speed. Their presumed paths are indicated by the broken lines. The square encloses the portion of the sky covered by the photograph on the facing page. Hatched region is Milky Way. Zeta Persei group is at upper right.

ZETA PERSEI ASSOCIATION is seen in the photograph at the top of this page. The diagram at the bottom shows the group's brightest stars, two of which, Zeta Persei and Xi Persei, are labeled. The arrows indicate the directions in which the stars are traveling and the distances they will cover during the next 500,000 years. White hatching represents a bright cloud; black hatching, dark.

that they could have only a temporary existence and therefore offered an opportunity to study evolutionary developments in the regions where they were found. The individual stars in an association, like all other stars in our galaxy, move at very high speed in great orbits around the center of the wheeling galaxy, and they also move with respect to one another. Ambartzumian observed that within at most 100 million years an O-association would be so dispersed by these motions that it would cease to be recognizable as a group. The associations we see must therefore be comparatively young. This suggests that during the five-billion-year life of our galaxy other associations may have arisen and disappeared, and that new ones may appear in the future. Indeed, galaxies which seem to be in an older stage of evolution than ours give evidence of having young O-associations [*see photograph on page 41*].

Let us look at an association then, as a birthplace of stars. A good example is a nearby association in the constellation Perseus, called the Zeta Persei association after its brightest member, the star Zeta Persei [*see the opposite page*]. The association members are indicated in the drawing below the photograph. Some parts of the region in which they lie are hidden by dark clouds of gas; others have bright clouds excited by the brilliant stars of the association.

The positions of these stars, which are among the brightest in the sky, have been measured for a century or more by many observatories all over the world. During that time the observed positions have moved slightly, and from the displacement we can calculate the rate of motion of the stars across our line of sight. When we extrapolate their motions backward and forward in time, we arrive at the surprising discovery that the stars in the outer regions of the Zeta Persei association must have started from a common center no longer than about a million and a half years ago. In all likelihood they were born, at least in their present form, at that time.

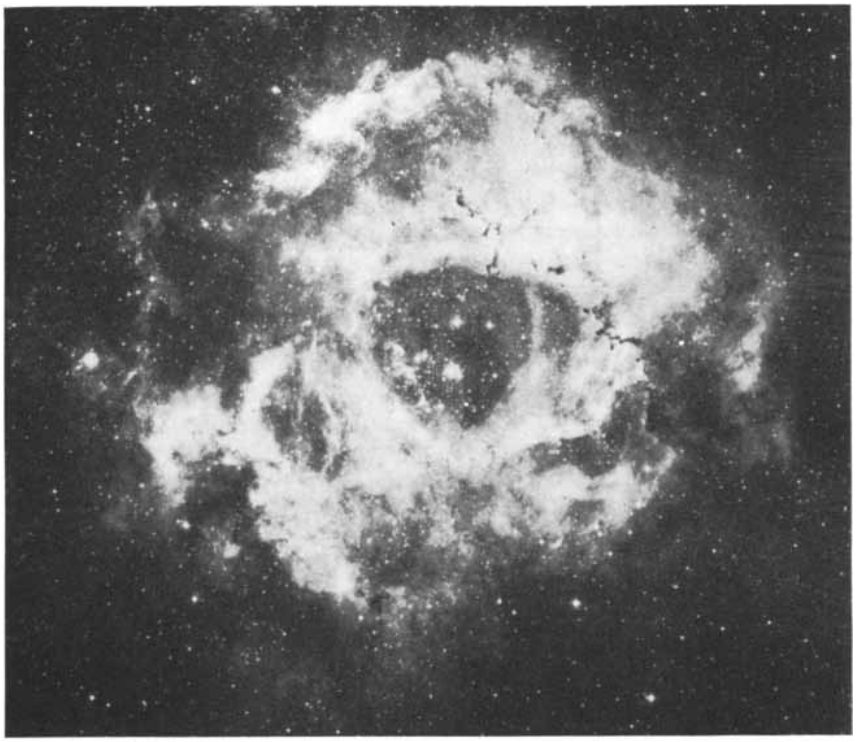
It is certainly astonishing to encounter stars so youthful. Even on the short time scale of life on the Earth they appeared only yesterday. When these stars were born, mammals had long since arrived on the Earth, and man was making his appearance!

The associations not only indicate the young stars' birth date but also may tell us something about the circumstances under which they were born. Astronomers today generally agree that stars probably are formed from dense clouds of gas, which condense by gravitational attraction until they finally begin to radiate as stars and follow definite orbits in the galaxy. As Bart J. Bok of the Harvard College Observatory has suggested, stars seem to evolve from small, dense clouds of dust and gas which he named globules. Now the Zeta Persei association contains very dense clouds, and so do other associations. Indeed, one of the outstanding characteristics of the birthplaces of the hot young stars is the fact that a great deal of interstellar gas is always present.

Assuming that stars are born of gas clouds, what causes them to start racing away from their birthplace as soon as they are born? In the Zeta Persei association the young stars are fleeing from the center at a speed, on the average, of 14 kilometers per second, and the star named Xi Persei is traveling at 50 kilometers per second—110,000 miles per hour! Moreover, some of the gas clouds also are racing outward at like speeds. What physical process could give the stars and clouds these high velocities?

Jan H. Oort of the Netherlands has suggested a plausible theory. It begins by considering an association such as the one called NGC 2244, some 5,000 light-years from us in the constellation Monoceros [*upper photograph on next page*]. This association is a comparatively compact group of very bright O and B stars surrounded by a huge cloud of hydrogen gas. The total mass of the cloud

SCORPIO-CENTAURUS ASSOCIATION contains clearly visible luminous clouds of gas among a group of dark clouds. So far only about 50 stellar associations have been surveyed by astronomers. There are probably several thousand more of them within our galaxy.



ROSETTE NEBULA is a gas cloud which surrounds the bright stars of the association NGC 2244. Radiation from the stars ionizes the gas, heating it and raising its pressure.

DARK WEDGES pointing in toward the nebula M 16 may be dense clouds of nonluminous gas. Bright rims look like hot gas which is pushing its way out between the dark clouds.

is estimated to be about 40,000 times the mass of the sun. The stars in the center, including not only the bright members of the association but also the fainter ones, are judged to have a total mass 1,000 times that of the sun, so that the cloud contains a far greater amount of matter than the stars themselves.

We assume that the young stars in the center were formed from dense globules of gas right where they are now. The hot stars radiate a considerable amount of energy into the surrounding cloud; this radiation ionizes the hydrogen and heats up the inner regions of the cloud. The temperature of this part of the cloud is estimated to be about 10,000 degrees above absolute zero. Such a temperature would be about a hundredfold increase over the original temperature before the stars were formed. That means the gas pressure in the inner part of the cloud also must have increased a hundredfold. We may suppose that the pressure of the expanding gas, pushing against the cool outer parts of the cloud, might compress the gas in a transition zone into a dense layer. In this compressed layer a new generation of stars might be born. And because of the expansion under way, these new stars would start life flying at a high rate of speed away from the center. Such a process would account for the expansion and flight of stars that we see in the Zeta Persei and other associations.

There is another type of association which may exhibit a variation of the same process. Consider the association called M 16 [*photograph at the left*]. Here the cloud complex surrounding the central stars is punctuated by dark clouds which are roughly wedge-shaped, with the point of the wedge toward the center. Along the side edges of each wedge are narrow rims of brightly luminous gas. It looks as if hot gas from the center is streaming along these edges. Are the dark clouds dense concentrations of cool gas which the hot expanding gas cannot push away from the center rapidly? If they are indeed dense clouds, we may expect that new stars will be born in them in the future.

The pressure theory of the birth and flight of stars still has many questions to answer. Is gas in the cloud actually compressed into dense layers under pressure from the center? Could the pressure process account for the very high speeds of the stars in the expanding associations? We do not have enough quantitative data to confirm these hy-

potheses. And there are some observed motions of hot young stars which apparently cannot be explained by the pressure theory.

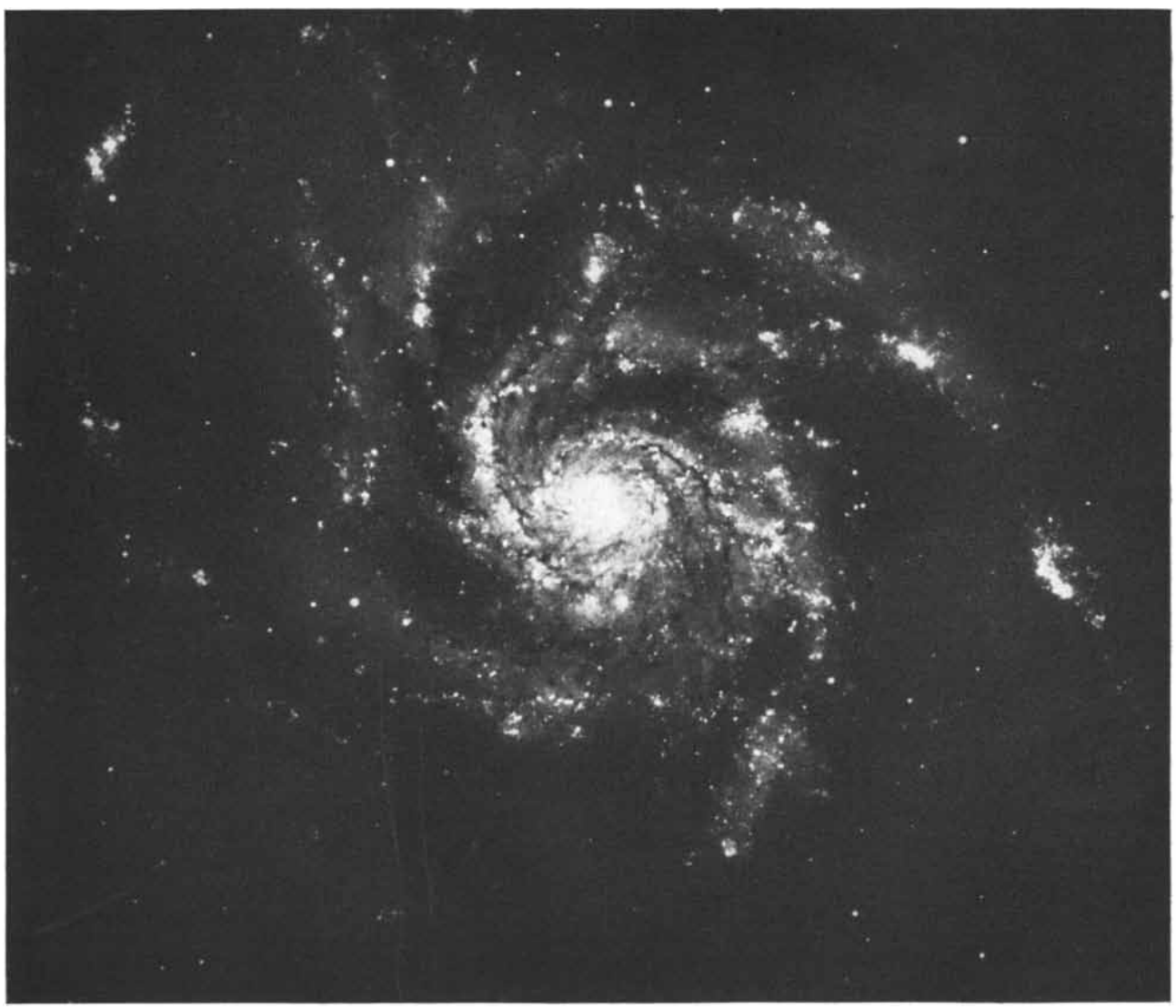
The most remarkable of these occurs in the constellation of Orion. Orion has a group of very bright stars which form a typical O-association. But far out beyond the group are three brilliant young stars which look like prodigiously fleet runaways. Their names are AE Aurigae, Mu Columbae and 53 Arietis [*see illustration on page 37*]. Whereas the average velocity of members of the association is eight kilometers per second, AE Aurigae and Mu Columbae are traveling at about 130 k.p.s. and 53 Arietis at 70 k.p.s. Yet the three stars are moving away from the same center and seem to have been born in the Orion association. They are hot stars of the same spectral type, O and B, as the bright stars which make up the central group in this association.

What can this mean? The three distant outriders carry among them more kinetic energy than all the other hundreds of stars in the association combined. What sort of process could have apportioned kinetic energy in this freak fashion?

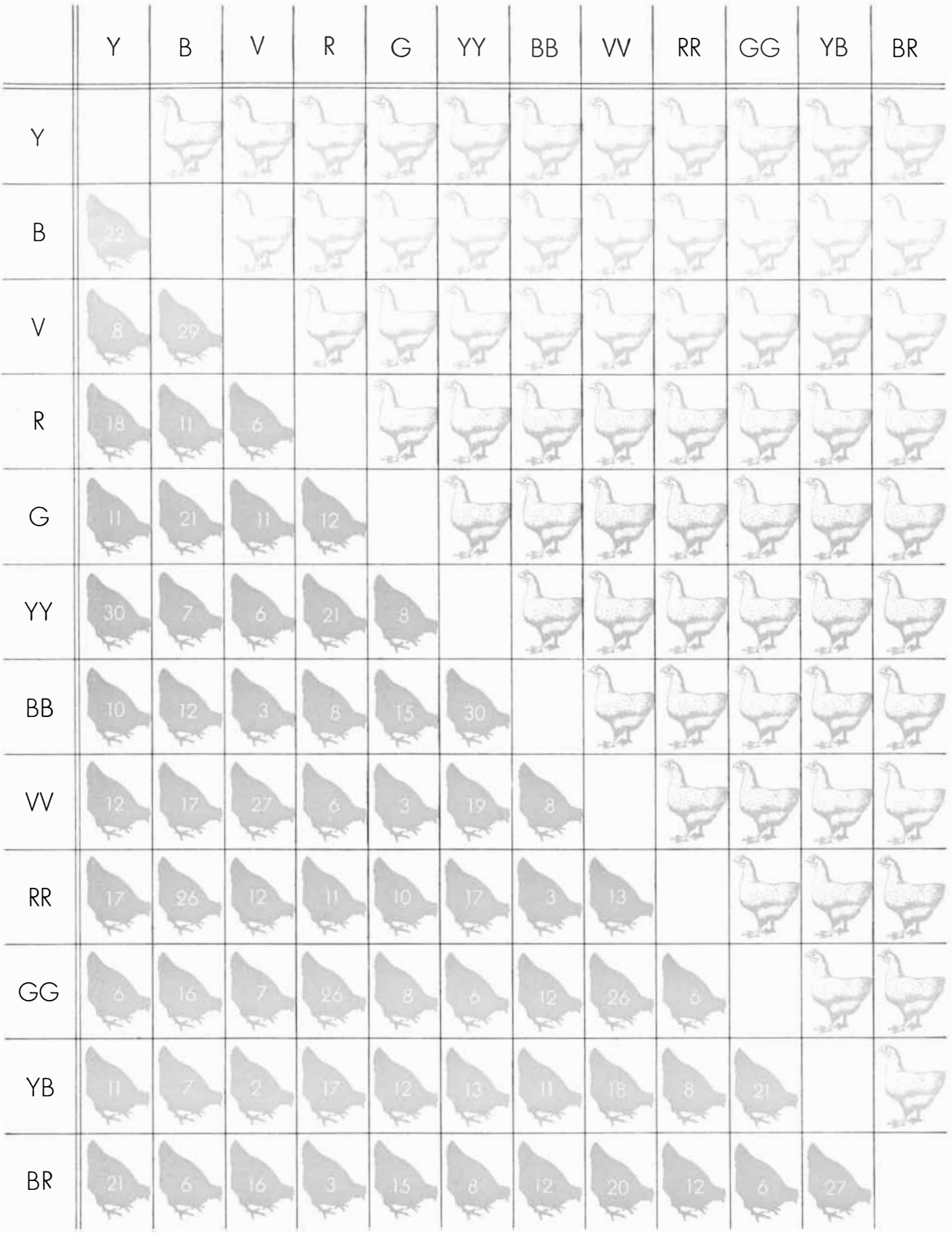
Two of the stars—AE Aurigae and Mu Columbae—are traveling in precisely opposite directions and seem to have been born simultaneously about 2.8 million years ago. It is tempting to guess that they were twin offspring of a single prodigious and violent event. The event must have been unique, for no other pair of stars like this has so far been discovered in the heavens.

Lyman Spitzer of Princeton University has proposed the possibility of a rocket effect—a recoil between ionized gas and a dense cloud—which might accelerate gas clouds (and the stars born in them) to velocities as high as 50 kilometers per second, but the speeds of the strange young twins fleeing from Orion are considerably higher than this.

The renewed study of the star associations has opened many intriguing prospects. About 50 of these associations have already been surveyed, and probably there are several thousand more in our galaxy. It has become clear that this is the place to investigate the childhood of stars and the mysterious process of their birth, which undoubtedly is still taking place at the present time.



BRIGHT KNOTS in the arms of the spiral nebula M 101 are probably stellar associations which the telescope cannot resolve into individual stars. This photograph and the ones on the opposite page were made with the 200-inch telescope on Palomar Mountain.



PECK-ORDER IS DEPICTED in this chart of an experimental flock of 12 Rhode Island Red hens. Each hen in the flock was marked with either one or two colors: yellow (Y), blue (B), violet (V), red (R) and green (G). The hen with a yellow marking (*column at far left*) pecked all 11 of the other hens and was pecked by none of them. The number of times it pecked each of them is indicated by the numbers in the column. The hen with a blue marking (*second column*) pecked nine of the other hens but was pecked by the hen with a yellow marking. The hen with a blue and red marking (*column at far right*) pecked none of the other hens and was pecked by all. The hens with bowed heads (*solid color*) indicate the number of hens submissive to the hen in that column. The hens with upright heads (*open color*) indicate the number of hens that are dominant over the hen in that column.

THE SOCIAL ORDER OF CHICKENS

Both psychologists and farmers utilize the hierarchy formed in flocks of hens or roosters, in which the top-ranking bird pecks all the others and the bottom-ranking bird pecks none

by A. M. Guhl

During the past 30 years the social organization and behavior of chickens has interested many investigators, and its study has produced a great deal of fascinating information. The main theme of the investigation has been the trait of dominance, or bossism, but it has also shed important light on other questions of psychology, sociology and biology, and has been helpful in practical poultry husbandry. This article will report recent findings at our zoology laboratory at Kansas State College.

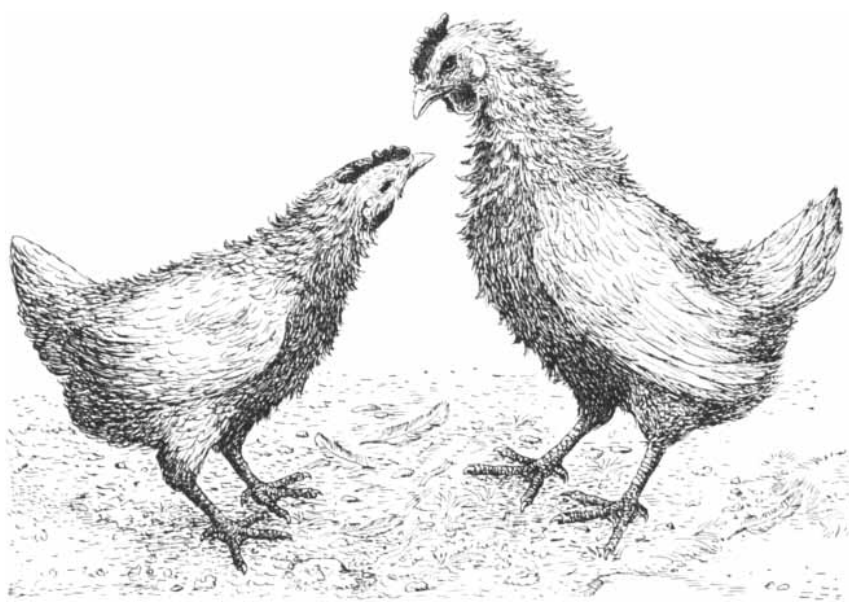
It was T. Schjelderup-Ebbe, a Norwegian psychologist, who discovered the peck-order among chickens. He found that in any flock one hen usually dominated all the others: she could peck any without being pecked in return. Second came a hen which pecked all but the top hen, and the rest were arranged in a descending hierarchy ending in a hapless hen which was pecked by all and could peck no one. Cocks do not normally peck hens, but they have their own peck-order, so a breeding flock usually has two hierarchies, one for each sex.

The late W. C. Allee and his students at the University of Chicago found that the male sex hormone increases aggressiveness, so that hens given injections of this hormone fight their way up the social ladder. The female hormone tends to have the opposite effect, making injected individuals more submissive. It is common knowledge that a castrate is more docile than the normal of the species. However, capons will and do form peck-orders and may engage in some harmless fighting.

When grown birds that are strangers to one another are put together in a pen, they engage in a series of single combats, each pairing off against one opponent at a time, until a peck-order has been established for the whole flock. Some individuals submit without a fight, because of lack of aggressiveness, poor health or lack of fighting skill. Once the peck-order has been determined, pecking begins to decline in frequency as members of the hierarchy recognize their superiors; eventually a mere raising or lowering of the head may be enough to signify dominance or submission, respectively. Thus the flock becomes comparatively peaceful and conserves energy.

In flocks of birds reared together from hatching, the dominance order develops gradually. Downy chicks rarely peck: they go no farther than a threatening posture or jump. As they grow older, fighting begins, and it may be repeated frequently before certain individuals learn to give way habitually to others. Peck-orders may be established at 10 weeks of age among pullets and somewhat earlier among cockerels.

A chicken's memory is short. Hens that have been separated for two weeks or more will fight the battle for dominance all over again when they are brought together. If a strange bird enters an organized flock, it has to fight each of the residents to establish its status. Obviously only an exceptionally aggressive outsider can win a respectable rank in the social scale under these circumstances. W. C. Sanctuary at the University of Massachusetts found that when flocks of hens were mixed, there



PECK-ORDER IS FORMED by a series of individual combats among the members of a newly established flock. This drawing depicts two Rhode Island Red pullets fighting.

was severe disruption, sometimes causing some birds to stop laying.

Such is the basic social structure of chickens. Now let us examine it more closely. To begin with, what are the advantages of high social status?

Naturally hens that rank high in the peck-order have privileges—first chance at the food trough, the dusting areas, the roost and the nest boxes. The low members of the hierarchy may find themselves driven about ruthlessly in the pen, especially during the earlier phase of peck-order formation. Much of the time they keep out of the way of their superiors in secluded places. They have a cowed, submissive appearance—the head usually lowered, the body feathers ruffled and unpreened. By contrast the high-ranking hens strut proudly like pampered show horses.

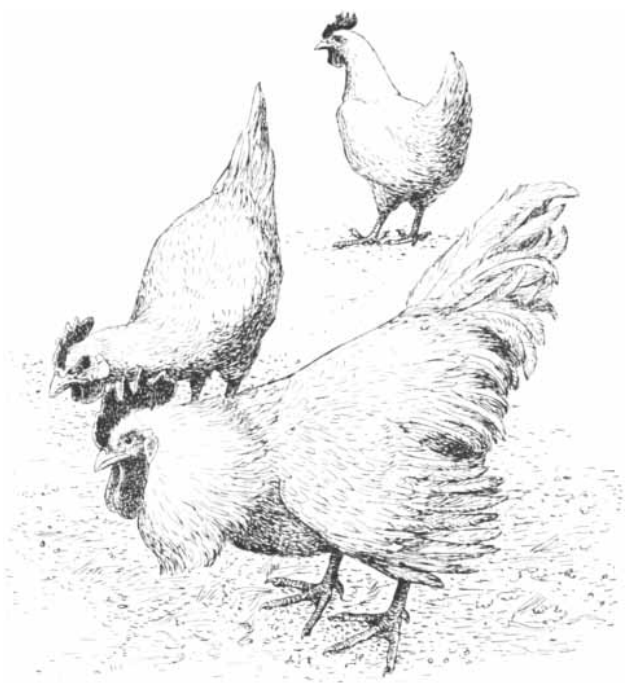
We have found that in a flock of young hens the high-ranking birds feed regularly during the day and crowd together on the roosts for warmth at night, whereas the low-ranking birds have to feed at twilight or early in the morning while their superiors are roosting, and at night they hover timidly on the fringes of the roosting group, often singly, even when temperatures drop below freezing. The low-ranking pullets take longer to reach sexual maturity than those of privileged status.

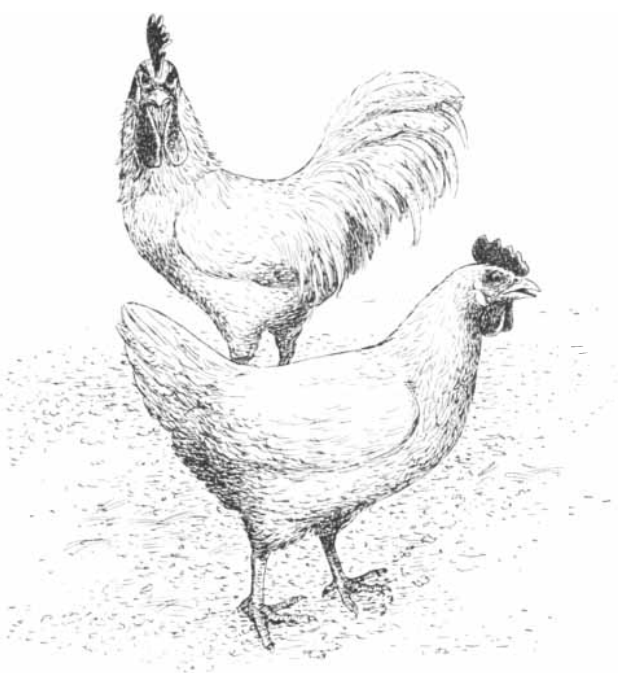
To see how social disorganization affected productivity, we compared two flocks, of which one was allowed to attain a stable peck-order and the other was kept disrupted by frequent shifting of its membership. Birds in the unstable flock fought more, ate less food, gained less weight and suffered many more wounds. The latest comers had the poorest position; the top ranks were occupied by those that had been in the shifting flock longest. In other words, chickens have seniority rights. There are, however, variations of individual aggressiveness: a hen that spends a short time daily with each of several flocks may have different ranks in the different flocks.

How does the peck-order influence sexual behavior? The question of course has considerable practical importance for poultrymen. We investigated it by several rather complex observational experiments.

The observable sexual activity of a male chicken follows a characteristic pattern: courting, treading and the act of coition itself. Most conspicuous of his courting maneuvers is a wing-flutter and dance, but sometimes he uses a more subtle approach to the female, merely extending his head toward or over her, with or without raising his hackle. If the hen responds by assuming what is called a sexual crouch, the male grips her comb or hackle with his beak and, standing on her outstretched wings, moves his feet up and down with a treading action prior to coition. A female chicken, in response to a male's courting, may react in one of three simple ways: indifference, avoidance or the cooperative crouch.

We were interested first to find out how hens would respond to courtship by males which lacked the normal male dominance over them. We therefore castrated some cockerels, depriving them of the advantage of masculine aggressiveness, and raised them in a flock of pullets where they were subjected to the peck-order contest. Some of the capons fell in the intermediate ranks, being dominated by some females. We then treated these capons with the hormone estrogen, which restored their sex drive without increasing their ag-





SEXUAL BEHAVIOR of chickens involves four kinds of maneuver: courting, avoiding, crouching and treading. In the first drawing a White Leghorn rooster (*foreground*) courts a hen by performing a waltz. The hen may respond either by avoiding the

gressiveness. Hens that ranked below these males in the peck-order mated readily with them. But hens that outranked them repelled their advances and drove them wildly about the pen. Evidently among chickens dominance by the male is a prerequisite for sexual acceptance by the female. However, we also noted that females fled from males which were too aggressive sexually.

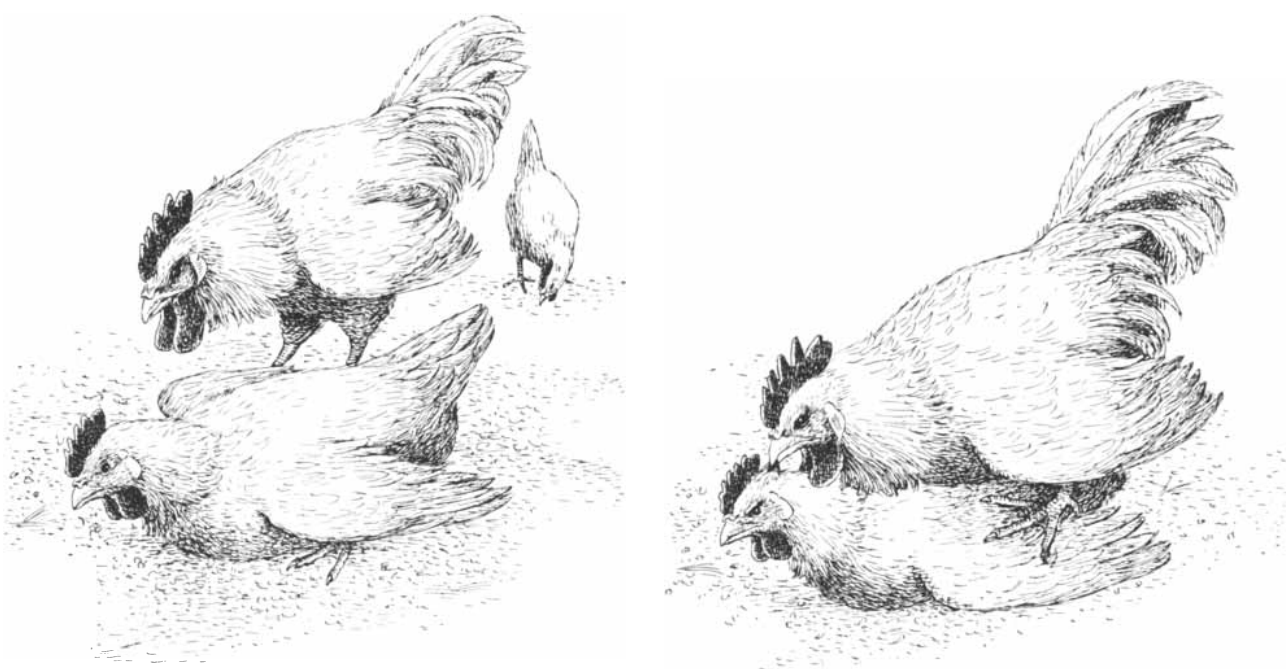
In all-male flocks of young chickens the males often perform sexual treading upon one another, presumably because they have no normal outlet for their sexual drive. Usually the low-ranking males are the objects of these aberrant treadings, and some are driven and trodden so incessantly that they are killed. In flocks of hens, similarly, dominant females may act the male role and tread on hens lower in the peck-order. This behavior is difficult to explain, for the treading hens are not necessarily masculine in any way; they usually respond normally to the advances of a male in the same flock.

Another experiment showed, as was to be expected, that males at the top of the peck-order win out over their inferiors in any competition for mating with hens. When a small group of cocks which had previously shown no significant individual differences in sex drive was placed in a pen with hens, the dominant male was most successful in mating with the hens, while the male ranking lowest in the group's peck-order was least successful. The dominant one suppressed his inferiors' treading to varying degrees. One male was completely suppressed sexually; he failed to react to the hens he knew even when the other males were removed. This condition was called psychological castration.

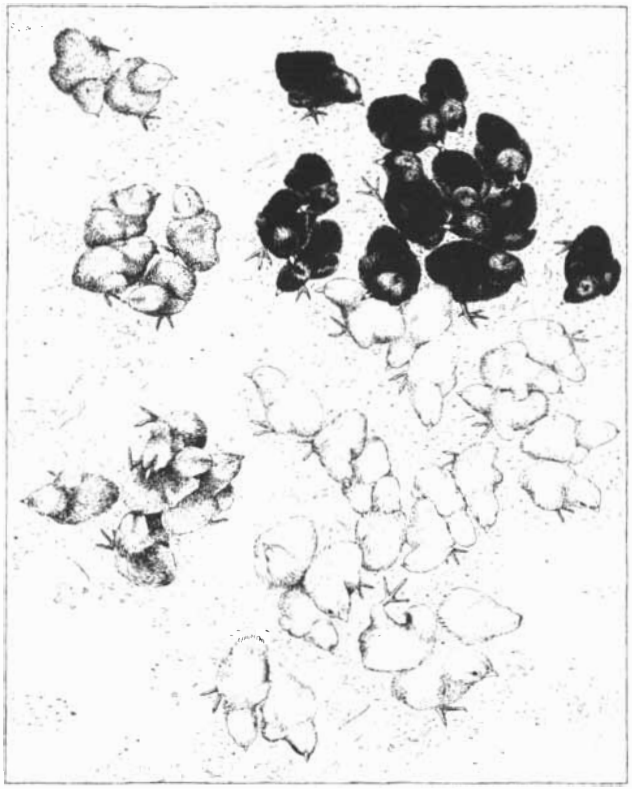
One would naturally assume that the males most successful in mating would also sire the most offspring, but to make sure we carried out some special experiments with the cooperation of the poultry geneticist D. C. Warren. We used males of different breeds (Rhode Island Red, Barred Rock, White Leghorn), and the distinctively marked offspring demonstrated that the most dominant males did indeed father the most chicks. The lowest-ranking cock in one flock failed to fertilize even one egg.

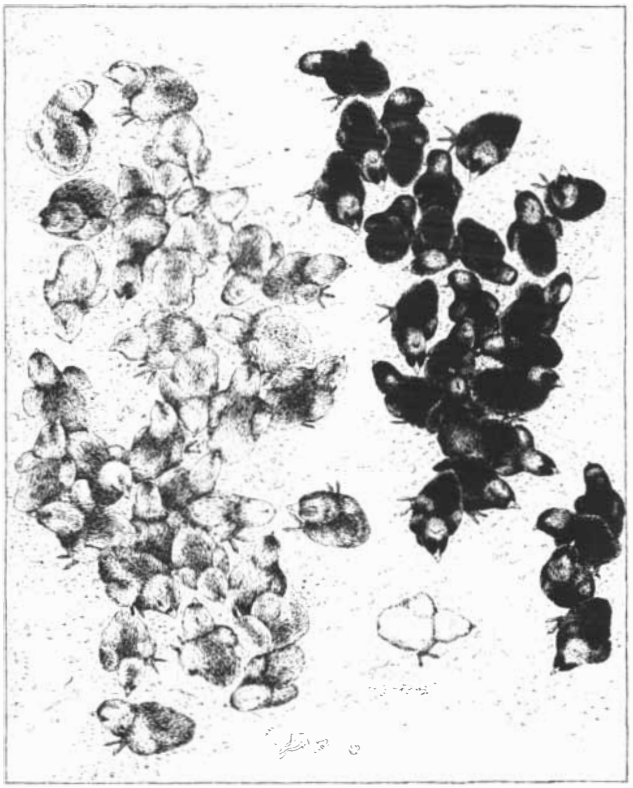
What of the hens; how does their rank in the peck-order affect their sexual activity? There were already hints that the more dominant females are less likely to submit to coition, and we undertook to investigate this systematically. We raised some large flocks of 30 to 40 pullets each, and after they had established peck-orders, we divided each flock into three groups—the top third, the middle third and the bottom third of the peck-order. The ranking within each group remained the same as before, but each pullet now had fewer birds to dominate or be dominated by. This significantly changed their receptivity to male courtship. The hens in the top third, which had been comparatively unreceptive to males, became more submissive to them (as evidenced by the frequency of crouching), and the middle and bottom thirds became less submissive. In other words, the higher hens stand on the social scale, the less likely they are to mate, whereas the male improves his chances by high social status.

In these tests we noted that the females' sexual interest was stimulated each time a new male was released in their pen, but their interest was soon sated (within six to nine minutes), and thereafter they tended to avoid the male. On the other hand, the more reluctant the females were, the more ardently the males pressed their courtship: they com-



rooster (*second drawing*) or crouching with her wings spread out (*third drawing*). Crouching is a strong stimulus for the rooster to mount the hen. Before coition he stands on her wings, seizes her hackle with his beak and moves his feet with a treading action.



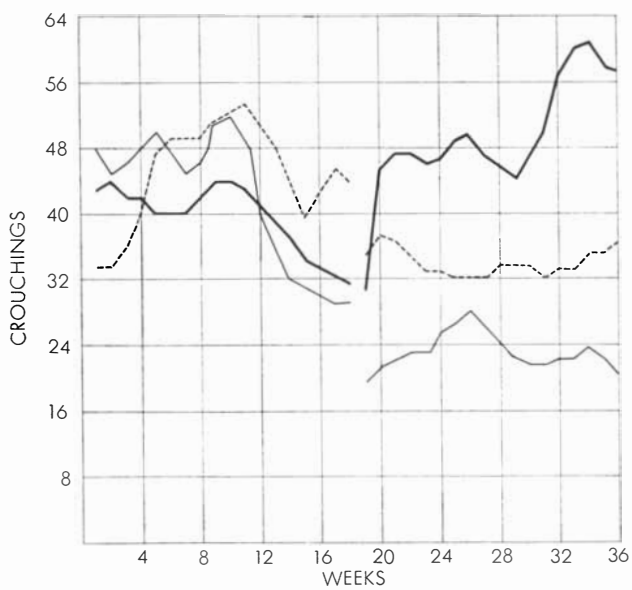


CHICKS at left hatched from eggs laid by hens artificially inseminated with a mixture of sperm from three roosters: a Rhode Island Red (*siring darkest chicks in drawing*), a Barred Plymouth Rock (*lighter chicks*) and a White Leghorn (*white chicks*). The chicks at right were sired by the same roosters in a flock of hens. Difference in distribution was due to social status of the roosters.

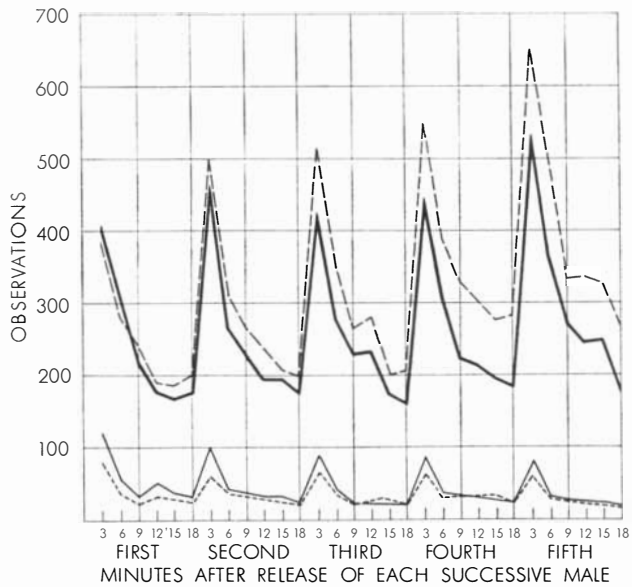
pensated for the hens' reduced receptivity by increasing their displays.

Male chickens vary considerably in sex drive. Their sexuality is not necessarily related to their aggressiveness, or standing in the peck-order. Consequently a dominant male with a low sex drive may reduce the fertility of a flock of hens by preventing other males from mating. This suggests that for breeding flocks poultrymen should select males of high sexuality and effectiveness in courting.

We have found that chickens are excellent animals for experimental investigation of general principles of social behavior. They add a great deal to the understanding of various matters, such as aggressiveness and courtship, which is being gained from studies of many animals, from the stickleback fish to the chimpanzee.



CROUCHINGS of hens per week were altered by dividing flock into top third of the peck order (*heavy line*), middle third (*broken line*) and bottom third (*light line*) after 18 weeks of courting.



OBSERVATIONS of courting (*solid line at top*), avoiding (*broken line at top*), crouching (*solid line at bottom*) and treading (*broken line at bottom*) changed with introduction of each new rooster.

Kodak reports to laboratories on:

some information we hope you'll use and some we hope you won't . . . how to carve a fancy design on a microscopic bit of semi-conductor

Data for the times

As a kind of a public service, we feel we ought to print the following table:

KODAK FILM	Kodak Developer	Time (min.)	1,000-KVP X-rays—Roentgens for density of		
			0.3 net	1.0 gross	2.0 gross
1. Kodak Royal Pan Film	DK-60a	4	1.2	13.2	440
2. Eastman Plus-X Panchromatic Negative Film	D-76	8	3.7	19	450
3. Kodak Commercial Film	DK-50	5	4.3	47	305
4. Kodak Contrast Process Panchromatic Film	D-11	5	11.5	36	98
5. Kodak Infrared Aerographic Film	D-19	9.6	1.2	4.0	18
6. Kodak Linagraph Ortho Film	D-19	7	1.1	3.2	12
7. Kodak Super-XX Aerographic Film	D-19	9.6	1.2	3.8	17
8. Kodalith Ortho Film, Type 2	Kodalith	2.25	—	1400	1700
9. Recordak Micro-File Panchromatic Film	Kodagraph	5	90	220	560

We have three reasons for printing it, in decreasing order of importance.

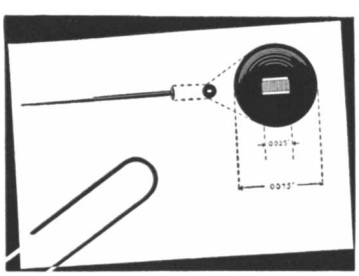
1) In the event of nuclear disaster, pieces of film that survive lighttight might serve as fortuitous dosimeters. Few American population centers of 10,000 souls or more wouldn't contain at least a box or two of such a popular product as *Kodak Royal Pan Film*. Giving it the above-indicated processing normally recommended for that film would provide a radiological survey party with a quick and rough estimate of the amount of prompt radiation that hit where the film was stored. The table neglects the possibility of solarization, but perhaps this is an excessively lugubrious thought.

2) In these nuclear times, the question often arises of how much radiation it takes to spoil film for its intended purpose. Here is a guide to tolerance judgments, since the sensitivity of a particular photographic material is essentially the same for all radiations harder than 1,000-kvp x-rays.

3) It's an excuse to tick off a few film names you might like to know about. No. 2 is one of the main threads for Hollywood's loom of glamour and glory. No. 3 is sheet film with good tone rendition for monochrome subjects, slow enough for processing by inspection under a relatively bright Series 1 Safelight. No. 4 is the basic sheet film for black-and-white photomicrography. No. 5 has sensitivity out to nearly 10,000Å and comes in widths up to 9½″ and lengths up to 390 feet. No. 6 is 16mm and 35mm film for recording repetitive patterns from green-emitting c-r tubes, unaffected by reddish cathode glow. No. 7 is the world's No. 1 film for aerial photography. No. 8 is a sheet film that gives either inky blackness or diaphanous clarity and nothing much between. And No. 9 provides 16mm or 35mm sanctuary for records by the billions.

For more detailed information on the radiation sensitivity of more Kodak films, write Eastman Kodak Company, X-ray Division, Rochester 4, N. Y., who hope that the only film ever given an opportunity to soak up roentgens will be Kodak X-ray Film.

Here's how



Here is how to carve a microscopic bit of a semi-conductor like germanium or silicon into as intricate a structure as you need to beat a complex vacuum tube at its own game:

Draw up the pattern nice and big with India ink. Photograph it down to a stencil of desired size with a good lens (like a *Kodak Process Ektar Lens*) on a virtually grainless, all-or-none material (like *Kodalith Ortho Film* or, for really tiny work, a *Kodak High Resolution Plate*).

Saw out a blank of the semi-conductor crystal. Lap and polish it, finishing up with 0.5μ grid-size diamond paste. Etch off the remaining few microns of work-strained layer. Wash in trichloroethylene, rinse in distilled water, and dry.

Avoiding daylight or ultraviolet, filter a little *Kodak Photo Resist*. With it, coat the polished semi-conductor surface thinly. Dry under a heat lamp. Hold the stencil tight against the semi-conductor by vacuum. Expose to an arc lamp. Immerse in *Kodak Photo Resist Developer*. Take out. Put on a few drops of *Kodak Photo Resist Dye* to make the developed image visible. Hold under a stream of tepid distilled water to wash away the resist where the dark portions of the stencil shielded it. Pull up the window shades. Blot off the surface moisture. Inspect the pattern with a microscope. If OK, bake for a few minutes to harden the resist. Let an etchant suitable to the specific semi-conductor remove it to any required depth in those areas where there is no resist left to resist.

Over the whole, deposit a metal electrically, chemically, or by evaporation. Immerse in *2-Ethoxyethyl Acetate** for 10 minutes and gently swab. This solvent, undeterred by the overlying metal film, removes the remaining resist.

There's your little triumph in applied solid state physics, complete with electrodes.

This is basically Bell Telephone Laboratories' idea, not ours. All we did was to suggest Kodak Photo Resist. *Apparently it was a good suggestion. Anybody else who wants any suggestions about the Kodak products involved can write Eastman Kodak Company, Graphic Reproduction Division, Rochester 4, N. Y.*

*Available as Eastman Organic Chemical No. P2378 at $2.05 for 1 kg. from our division, *Distillation Products Industries*, Rochester 3, N. Y.

Price quoted is subject to change without notice.

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*

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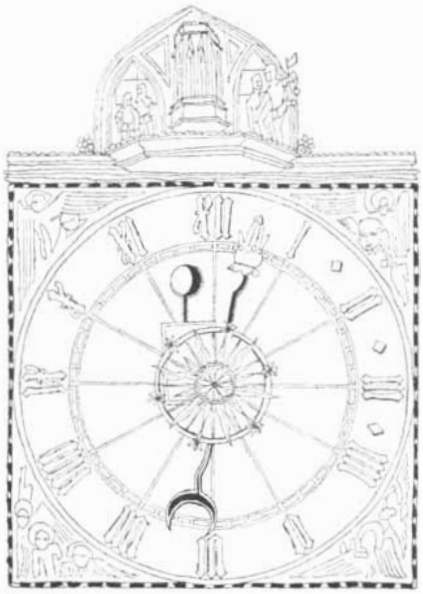


SCIENCE AND

A.A.A.S. in Atlanta

Racial segregation was a major theme at the annual meeting of the American Association for the Advancement of Science in Atlanta. Capping two years of controversy over the Association's decision to meet in that city, the A.A.A.S. Council set in motion a formal move which seems certain to bar any future convention of the group in a Southern city unless segregation is eliminated.

Four affiliates of the A.A.A.S.—the anthropology section, the American Association of Physical Anthropologists, the Society for American Archaeology and the Eastern Psychological Association—had refused to go to Atlanta. Some prominent Negro scientists also boycotted the meeting. Negroes who attended were unrestricted at official functions of the convention but were barred from white hotels and restaurants.

After discussion of members' protests, the A.A.A.S. Council voted to submit to immediate mail voting by its 328 members a resolution which said in part: "It is necessary and desirable that all members may freely meet for scientific discussions, the exchange of ideas and the diffusion of established knowledge. This they must be able to do in formal meetings and informal social gatherings. These objectives cannot be fulfilled if free association of the members is hindered by unnatural barriers. Therefore, be it resolved that [in the future] the annual meeting of the American Association for the Advancement of Science be held under conditions which will make possible the satisfaction of those ideals and requirements."

The resolution is thought to be almost certain of adoption.

For 1956 the chairman of the Association's board of directors and retiring president is George W. Beadle of the California Institute of Technology. The president is Paul B. Sears of Yale University. Laurence H. Snyder, geneticist and dean of the graduate school of the University of Oklahoma, was chosen president-elect, to take office as president in 1957.

The annual prizes at the meeting, each worth $1,000, were awarded as follows:

The Newcomb Cleveland prize to Seymour S. Cohen, of the University of Pennsylvania, for a paper reporting his discovery of the first clear-cut chemical difference in mutants: two different strains of a bacterial virus contained different amounts of glucose attached to their nucleic acids.

The Theobald Smith award in medical sciences to Robert Alan Good, of the University of Minnesota, for his studies of a condition in which patients lack immunity-conferring gamma globulin in their blood.

The John Scott medal to Edgar S. McFadden, of the Texas Agricultural and Mining College, for developing a rust-resistant bread wheat.

The William Procter prize for scientific achievement to Robert R. Williams, of the Research Corporation, for synthesizing vitamin B-1 and for other chemical achievements.

The A.A.A.S.–Anne Frankel Rosenthal memorial award in cancer research to Lloyd W. Law, of the National Cancer Institute, for his studies of leukemia.

The A.A.A.S. sociopsychological prize to Yehudi A. Cohen, of the Albert Einstein College of Medicine, for a study of the relation of infant-feeding schedules to the social outlook and economics of a society.

Among other interesting papers at the meeting was a report by A. E. Lilley and E. F. McClain, of the U. S. Naval Observatory, on the discovery of galaxies' motion in space (a "red shift") by means of radio astronomy. Radio waves from hydrogen gas in two galaxies in the constellation Cygnus were found to be lengthened beyond the usual 21 centimeters, and the amount of lengthening indicated that the galaxies are

THE CITIZEN

moving away from the earth at more than 10,000 miles per second. This figure agrees with the velocity of recession given by the visible red shift for the galaxies.

Karl Maramorosch, of the Rockefeller Institute for Medical Research, reported he had succeeded in growing a plant virus in a culture of animal tissue—that of an insect. "The notion that man may someday share a virus disease with plants," he said, "may not be mere fantasy."

A group of biochemists from the U. S. Public Health Service reported that the danger of contamination of food with DDT is not as great as had been thought. Feeding a group of volunteers daily doses of DDT, they found that after the poison accumulated to a certain level, apparently not harmful, the body excreted any additional DDT. The study was made by a team consisting of Wayland J. Hayes, Jr., William F. Durham and Cipriano Cueto, Jr.

Advanced Study at M.I.T.

The Massachusetts Institute of Technology last month announced a new School for Advanced Study for postdoctoral students. The school will be an integral part of M.I.T. and share its faculty members. The director will be Martin J. Buerger, a professor of mineralogy and crystallography.

M.I.T. president James R. Killian, Jr., pointed out that the Institute already attracts postdoctoral scholars from all over the world. This year about 100 such persons have registered at M.I.T. as "visiting fellows" or "guests." The new school will be a niche for them.

Killian added: "This demand for advanced study in part results from the fact that it now takes about as long to educate a fully professional physicist or chemist as it does a practicing physician. Further, the advance in knowledge makes it increasingly important for scholars to pursue advanced study beyond the level of graduate school and the doctor's degree."

Bronk Heads N.S.F. Board

Detlev W. Bronk, president of the Rockefeller Institute for Medical Research and of the National Academy

of Sciences, has been elected chairman of the governing board of the National Science Foundation, succeeding Chester I. Barnard. Paul M. Gross, dean of Duke University, was elected vice chairman of the board and chairman of its executive committee.

Just a Second

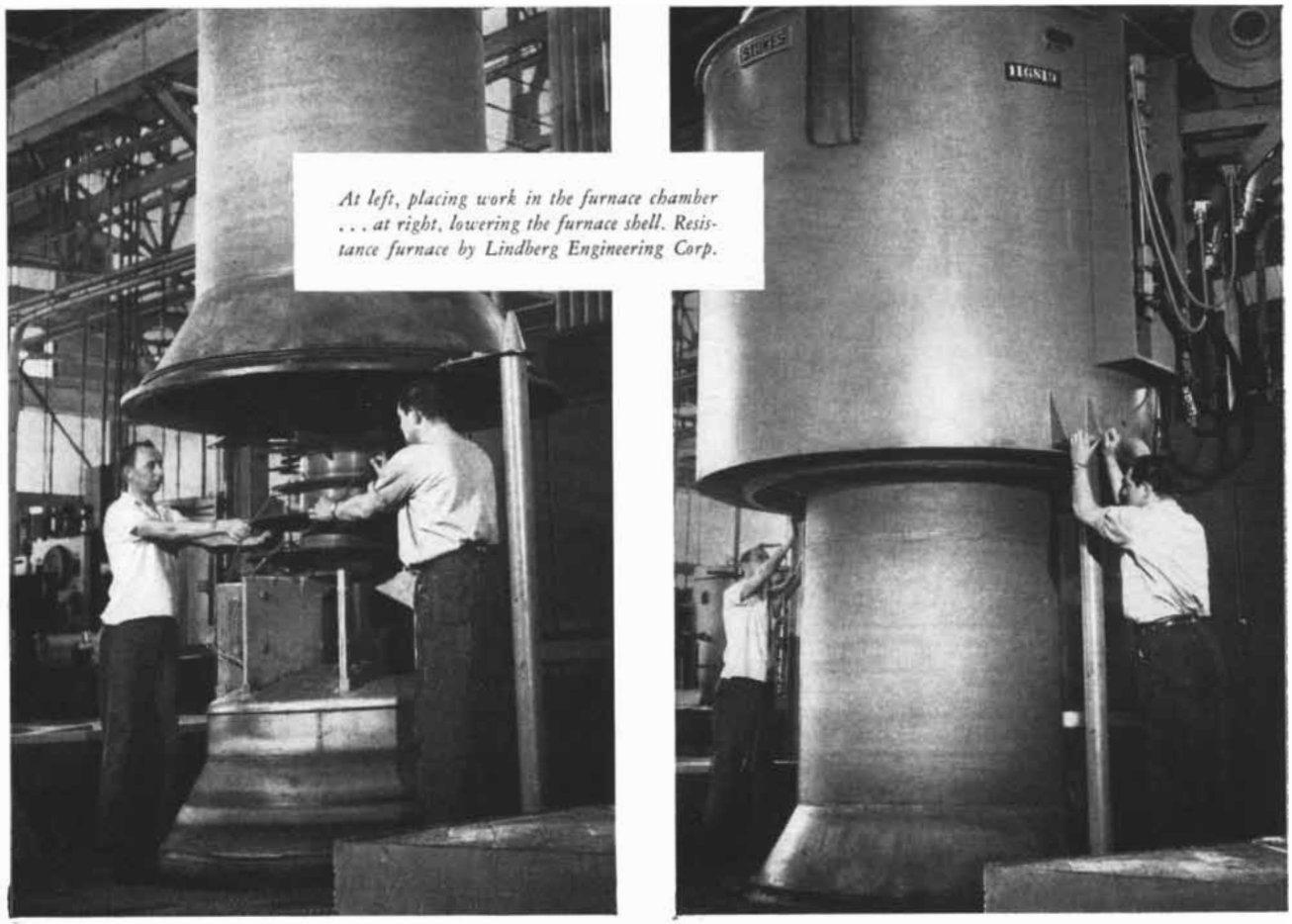
Should the standard unit of time be based on the revolutions of heavenly bodies or on vibrations of electrons in an atom? Recently Sir Edward C. Bullard of the British National Physical Laboratory proposed in *Nature* that a "physical second" be defined in terms of atomic frequencies. L. Essen and J. V. L. Parry of the same laboratory have built an apparatus with which they can measure one of the resonant frequencies of the cesium atom to an accuracy of one part in a billion. Bullard pointed out that if the second were tied to this frequency, there would be a readily available standard against which other timekeeping devices could be calibrated in a matter of minutes. An astronomical unit takes years to determine with comparable accuracy.

G. M. Clemence of the U. S. Naval Observatory replied in *Nature* that physicists should think twice before abandoning the astronomical time unit. He called attention to the fact that many physicists now use atomic vibration wavelengths as the standard of length, and if they define time in the same terms, they will have no way of checking the constancy of the velocity of light, which is its frequency times its wavelength. Furthermore, an atomic time standard would have no reference point: if the cesium clock were to stop, there would be no way of telling where to set it when it was started again.

Clemence believes that both standards will be useful, and that one should be continually checked against the other by experiment. There is no assurance that atoms and planets run on the same schedule. In fact, some theoretical physicists believe that the two time scales are continually changing with respect to each other.

Nuclear Anatomy

Physicists at Stanford University have developed a version of the electron microscope which can look into the nucleus of an atom and even "see" individual protons. The instrument makes no photographs but explores the nucleus by measuring the scattering of a beam of very-high-energy electrons.



At left, placing work in the furnace chamber . . . at right, lowering the furnace shell. Resistance furnace by Lindberg Engineering Corp.

Pratt & Whitney Aircraft Uses Versatile Stokes Furnace to Investigate Vacuum-Brazing of Jet Engine Components

New furnace useful for heat-treating and outgassing at high vacuum or under controlled atmospheres.

High-vacuum brazing, a logical development of vacuum metallurgy, is being investigated by numerous firms throughout the country. Typical of these investigations is the experimental work being done by Pratt & Whitney Aircraft, East Hartford, Conn., on vacuum-brazing of jet engine components. Tests indicate greater strength, ductility and uniformity of assemblies produced by this method.

Stokes furnace design for vacuum-brazing is practical . . . takes into account the problems of large-scale production. The Stokes dual-chamber design permits faster pumping cycles; provides complete accessibility of the work area and a large, uniform temperature zone. The equipment assures freedom from contamination. It can be used either with vacuum or with a variety of inert atmospheres. It provides fast heat-up and quick cooling.

Stokes engineers have a wealth of practical experience in vacuum metallurgy. We'll be glad to discuss the application of this fast-growing science to your production. For data on Stokes High-Vacuum Furnaces, write for Catalog 790. F. J. Stokes Machine Company, 5515 Tabor Road, Philadelphia 20, Pa.

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STOKES

From this information, the distribution of electric charge, which presumably means the location of particles in the nucleus, can be calculated.

Under the direction of Robert Hofstadter, the Stanford group has been using its microscope to examine nuclei in all parts of the periodic table, from hydrogen to uranium. They have discovered that in the larger nuclei there is an inner core of densely packed charge. The size of the core varies but its density is always the same. Around the core is a fuzzy "skin" which thins in charge density from the inside out. The nucleus of gold is one-third skin; that of calcium is half skin; smaller nuclei such as carbon are all skin—they have no core at all. All nuclei heavier than carbon have the same skin thickness; only the core varies in size.

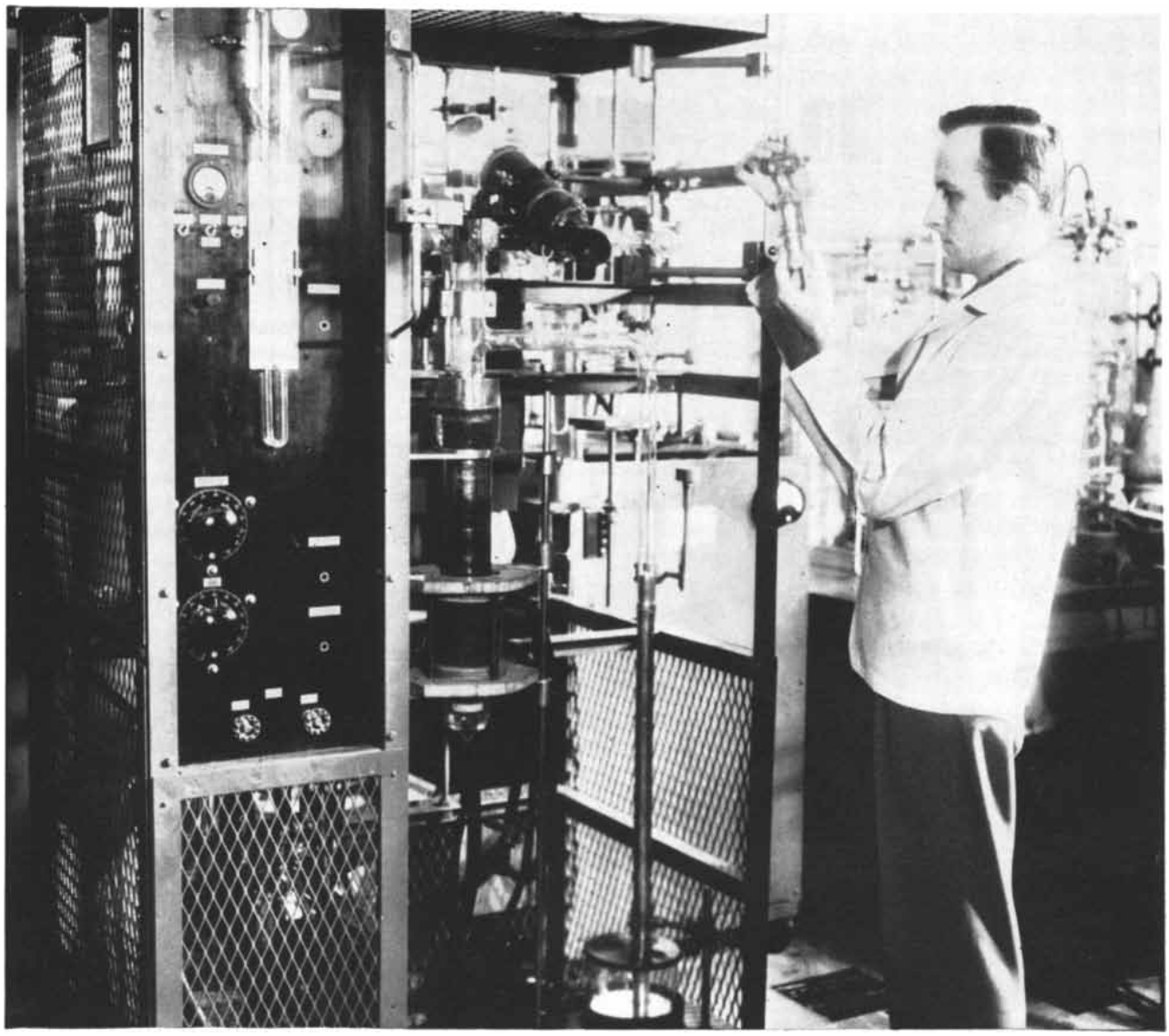
The scattering by the single proton that makes up the nucleus of hydrogen indicates that the proton occupies a sphere whose radius is about 7.5×10^{-14} centimeters.

Electrons for the microscope are provided by Stanford's 220-foot linear accelerator. After striking the target, they pass between the poles of a large magnet which focuses them on a detector, bringing electrons of different energies to focus at different points. This magnetic "spectrometer" is in effect the lens of the microscope. Most of the work thus far has been done with a 2½-ton magnet, which can focus electrons with energies up to 150 million electron volts. Now the Hofstadter group has a new spectrometer with a 30-ton magnet which can handle energies up to 550 Mev. This lens gives some three times the magnification of the old one. With it the physicists are beginning to investigate the helium atom, to find out how its two protons fit together.

Heavy Nitrogen

The recent discovery of a much cheaper way to purify heavy nitrogen may alter the thinking of atomic pile designers, suggests *Chemical & Engineering News*. Because it absorbs relatively few neutrons, the heavy isotope nitrogen 15 may make it possible to use soluble thorium nitrate in homogeneous breeder reactors. Up to now designers have been considering a slurry of insoluble thorium oxide powder, because the common isotope nitrogen 14 absorbs neutrons too readily.

The new process, developed by Columbia University chemists T. L. Taylor and William Spindel, separates the rare isotope N-15 from ordinary nitrogen



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by passing nitric oxide through an exchange column where nitric acid takes up the N-15. Taylor and Spindel estimate that a plant could turn out 50 pounds a day of the heavy isotope at a cost of around $450 to $500 per pound. In addition to the 50 pounds of interesting nitrogen, the plant would produce as a by-product 1,850 tons per day of sulfuric acid.

Pinch Effect

An interesting suggestion as to how a thermonuclear fusion reaction might be contained without using a material container was advanced last month by Richard E. Vollrath, professor of physics at the University of Southern California. He described an experiment in which hydrogen gas in a doughnut-shaped glass tube was heated by a circulating electric field and at the same time subjected to a strong magnetic field that held the hydrogen ions in a cluster away from the walls of the tube. The temperature was not high enough to set off fusion reactions, but the experiment at least indicated that a hot gas might be held together by a magnetic "pinch effect." The magazine *Nucleonics* said the effect was first demonstrated at the Los Alamos Scientific Laboratory by a group of physicists who named their apparatus the "Perhapsatron."

No Global Explosion

In his recent presidential address to the British Association for the Advancement of Science Sir Robert Robinson wondered whether the possibility of a hydrogen bomb starting a world-destroying chain reaction could really be excluded. "Do we really know enough about nuclear reactions to be sure that there is no loophole?" he asked.

M. H. L. Pryce, physics professor at the University of Bristol, replied in *Discovery* that "a nuclear bang, no matter how big, cannot trigger off a catastrophic chain reaction capable of destroying the earth."

The sequence of events Robinson had in mind would be triggered by a "rigged" hydrogen bomb. In this weapon a fission bomb sets off a fusion reaction in a mixture of lithium, deuterium and tritium. The fast neutrons produced by the fusion in turn fission uranium 238. The fear is specifically that this extremely energetic second fission process might cause fusion of materials in the earth's crust, notably hydrogen.

Pryce argues that there are basic differences between the hydrogen fusion

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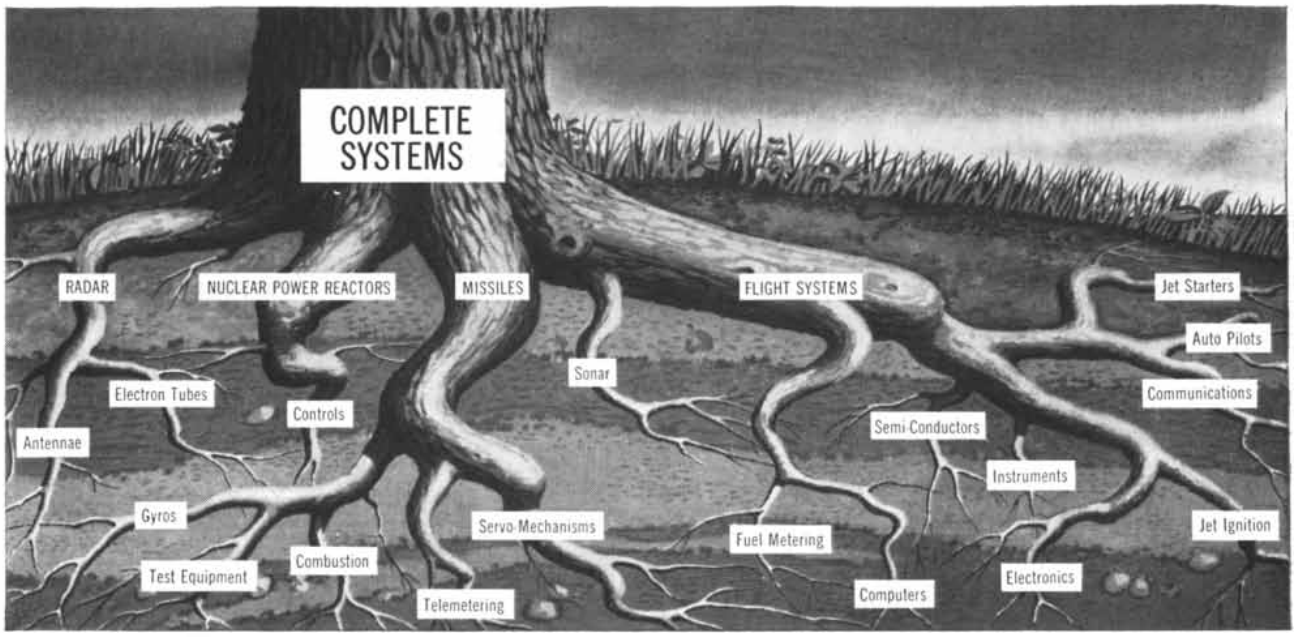

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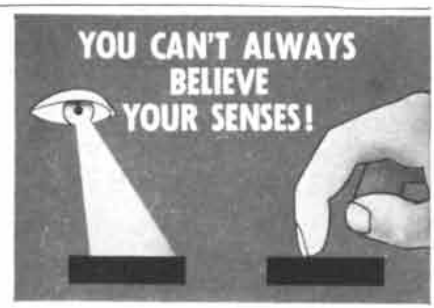

reactions in stars and those that have been produced by man. The welding of light hydrogen atoms that takes place in the sun is a very slow reaction, releasing its energy over eons of time. The immense gravitational pull of a star keeps this hydrogen compressed while the reaction proceeds. On earth, however, the hydrogen atoms are relatively sparse and there is not enough pressure, even at the center of the earth, to keep them close together long enough to react. Man-made fusion bombs must therefore be assembled from carefully selected fast-reacting materials.

Two North Stars

Polaris, the North Star, has an invisible twin, around which it revolves once every 30 years. The fact has been long suspected, but it was confirmed only recently by Elizabeth Roemer of the University of California.

Polaris is a Cepheid variable star which swells and contracts in a four-day cycle. The pulsations cause the spectrum of its light to shift, so that the star seems to be alternately approaching and receding from the earth. In 1929 J. H. Moore, then director of the University of California's Lick Observatory, noticed a slight change in the apparent motions between successive four-day periods. He concluded that the star had an actual motion as well as an apparent one. Careful study of the changes convinced him that they were caused by rotation around a companion star and would repeat after some 30 years. Now Dr. Roemer has checked the recent observations on Polaris against the ones used by Moore and found that they do indeed repeat as predicted.

Fats and Arteries

Does a fatty diet increase the likelihood of coronary disease? A survey reported in the British medical weekly *The Lancet* has given new evidence that it does. The study was made in Cape Town, South Africa, by B. Bronte-Stewart, a local physician; Ancel Keys, director of the University of Minnesota Laboratory of Physiological Hygiene, and J. F. Brock, medicine professor at the University of Cape Town.

The population of Cape Town consists mainly of three races, each with its own characteristic eating habits. The Bantu Negroes, at the bottom of the economic ladder, live mainly on corn meal, eat little fat and almost never contract coronary disease. The whites, at the top of the ladder, eat a diet rich

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in fats, and have about as much heart disease as Europeans or Americans. Midway between the Bantus and the whites are the "Cape Coloureds," who have an intermediate diet and some coronary trouble.

The researchers examined 364 healthy men between the ages of 40 and 58. They took particular note of the amount of cholesterol in their blood. Generally speaking, the whites had the most cholesterol, the Cape Coloureds less and the Bantus least. But the best-paid Bantus, who could afford to mix fat meat with their porridge or spread fat on their bread, had as much serum cholesterol as men in the other groups at the same economic level.

Fluoridation Decade

Some 22 million persons in 1,123 U. S. communities are already or soon will be drinking water enriched with fluorides. The supporters of this measure to reduce tooth decay among children have just received additional evidence to back their claims. The well-known 10-year study in Newburgh, N. Y., has ended with clear confirmation that fluoridation protects teeth without ill effects.

New York State public health officials examined the teeth and general health of 476 children in Newburgh, which has treated its water for 10 years, and 405 youngsters in Kingston, a nearby town on the Hudson River which does not fluoridate its water. In the six-to-nine age group Newburgh children, having drunk fluoridated water all their lives, had 58 per cent fewer cavities than children of corresponding ages in Kingston. Those who were born before fluoridation started benefited less. But even 16-year-olds in Newburgh had 41 per cent less tooth decay than their counterparts in Kingston.

None of the Newburgh children examined was disfigured by mottled tooth enamel. In skeletal maturity, height, weight, bone disorders, hemoglobin content of the blood and red-cell count there was no significant difference between the children of the two towns.

State Health Commissioner Herman E. Hilleboe concluded: "Fluoridation is safe, and it is effective."

Bringing up Tissue Cells

A cell in a piece of tissue is a member of a cooperative community. Isolated, it will not multiply in a nutrient medium, as a single-celled organism such as a bacterium will. Thus it has been practically impossible to raise col-

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One of a series of man's continuing efforts to control his environment
Heron's aeolipile reproduced by permission of the publishers, Abelard-Schuman, Inc., from JAMES WATT AND THE HISTORY OF STEAM POWER by Ivor B. Hart. Copyright 1949.

onies from individual tissue cells—a limitation which has handicapped studies of genetics and cell metabolism.

Two University of Colorado biophysicists have now found a way out of this dilemma. In the *Proceedings of the National Academy of Sciences* Theodore T. Puck and Philip I. Marcus describe a simple way to grow isolated tissue cells by means of growth-promoting substances supplied from other cells.

The technique depends on the fact that a moderate dose of X-rays stops cells from multiplying without actually killing them. The researchers line the bottom of a dish with irradiated tissue; then they fill it with nutrient solution. In the nutrient they suspend a glass slide dotted with a few isolated tissue cells. The tissue at the bottom continues to metabolize and produce growth-promoting substances, which continuously enrich the nutrient solution. Thus the cells on the slide have everything they need to multiply into colonies.

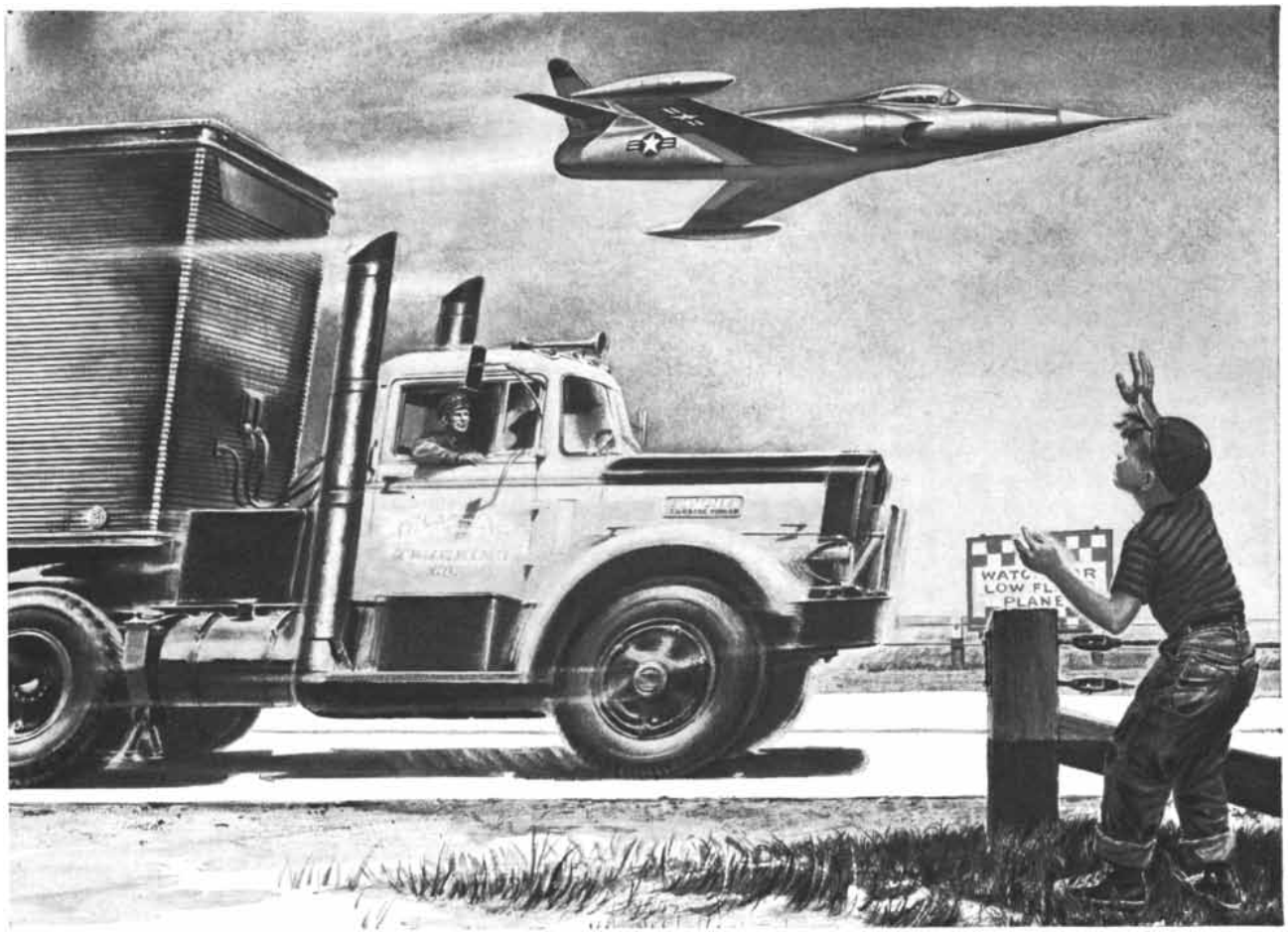
Puck and Marcus suggest that their method can prove important in studying the effects of radiation, virus invasion, toxic drugs and other stresses on tissue. It will be possible to pick out the occasional mutant cell that resists such attacks and grow from it a strain of resistant cells.

Idle and Happy

The notion that retirement makes a person discontented is contradicted by an interdepartmental study now in progress at Cornell University. Three fourths of about 700 recently retired men indicated that they are satisfied with their new way of life and are generally in good health, according to a report by Gordon F. Streib and Wayne E. Thompson of the department of sociology and anthropology.

The survey began in 1952 when 2,000 men around age 65 answered questions about their plans for the future and how they felt about retirement. Two years later those of the group who had retired were asked how they had adjusted to their new routines. The Cornell researchers plan to requestion the whole group repeatedly in coming years.

Most of the men had looked forward to retirement, and all but one sixth of these have enjoyed it. And two thirds of those who did not like the idea of retirement when they filled out the first questionnaire are nevertheless content to have stopped working. Generally speaking, those who are content with retirement were financially secure and had made plans for the future.



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Charles Darwin

In 1831 this gentle Englishman set forth on his famous voyage in the Beagle. After 28 years he published Origin of Species, which revolutionized man's view of nature and his place in it

by Loren C. Eiseley

In the autumn of 1831 the past and the future met and dined in London—in the guise of two young men who little realized where the years ahead would take them. One, Robert Fitzroy, was a sea captain who at 26 had already charted the remote, sea-beaten edges of the world and now proposed another long voyage. A religious man with a strong animosity toward the new-fangled geology, Captain Fitzroy wanted a naturalist who would share his experience of wild lands and refute those who used rocks to promote heretical whisperings. The young man who faced him across the table hesitated. Charles Darwin, four years Fitzroy's junior, was a gentleman idler after hounds who had failed at medicine and whose family, in desperation, hoped he might still succeed as a country parson. His mind shifted uncertainly from fox hunting in Shropshire to the thought of shooting llamas in South America. Did he really want to go? While he fumbled for a decision and the future hung irresolute, Captain Fitzroy took command.

"Fitzroy," wrote Darwin later to his sister Susan, "says the stormy sea is exaggerated; that if I do not choose to remain with them, I can at any time get home to England; and that if I like, I shall be left in some healthy, safe and nice country; that I shall always have assistance; that he has many books, all instruments, guns, at my service. . . . There is indeed a tide in the affairs of men, and I have experienced it. Dearest Susan, Goodbye."

They sailed from Devonport December 27, 1831, in H.M.S. *Beagle*, a 10-gun brig. Their plan was to survey the South American coastline and to carry a string of chronometrical measurements around the world. The voyage almost ended before it began, for they at once encountered a violent storm. "The sea ran very high," young Darwin recorded in his diary, "and the vessel pitched bows under and suffered most dreadfully; such a night I never passed, on every side nothing but misery; such a whistling of the wind and roar of the sea, the hoarse screams of the officers and shouts of the men, made a concert that I shall not soon forget." Captain Fitzroy and his officers held the ship on the sea by the grace of God and the cat-o'-nine-tails. With an almost irrational stubbornness Darwin decided, in spite of his uncomfortable discovery of his susceptibility to seasickness, that "I did right to accept the offer." When the *Beagle* was buffeted back into Plymouth Harbor, Darwin did not resign. His mind was made up. "If it is desirable to see the world," he wrote in his journal, "what a rare and excellent opportunity this is. Perhaps I may have the same opportunity of drilling my mind that I threw away at Cambridge."

So began the journey in which a great mind untouched by an old-fashioned classical education was to feed its hunger upon rocks and broken bits of bone at the world's end, and eventually was to shape from such diverse things as bird beaks and the fused wing-cases of island beetles a theory that would shake the foundations of scientific thought in all the countries of the earth.

The Intellectual Setting

The intellectual climate from which Darwin set forth on his historic voyage was predominantly conservative. Insular England had been horrified by the excesses of the French Revolution and was extremely wary of emerging new ideas which it attributed to "French atheists." Religious dogma still held its powerful influence over natural science. True, the 17th-century notion that the world had been created in 4004 B.C. was beginning to weaken in the face of naturalists' studies of the rocks and their succession of life forms. But the conception of a truly ancient and evolving planet was still unformed. No one could dream that the age of the earth was as vast as we now know it to be. And the notion of a continuity of events—of one animal changing by degrees into another—seemed to fly in the face not only of religious beliefs but also of common sense. Many of the greatest biologists of the time—men like Louis Agassiz and Richard Owen—tended to the belief that the successive forms of life in the geological record were all separate creations, some of which had simply been extinguished by historic accidents.

Yet Darwin did not compose the theory of evolution out of thin air. Like so many great scientific generalizations, the theory with which his name is associated had already had premonitory beginnings. All of the elements which were to enter into the theory were in men's minds and were being widely discussed during Darwin's college years. His own grandfather, Erasmus Darwin, who died seven years before Charles was born, had boldly proposed a theory of the "transmutation" of living forms. Jean Baptiste Lamarck had glimpsed a vision of evolutionary continuity. And Sir Charles Lyell—later to be Darwin's lifelong confidant—had opened the way for the evolutionary point of view by demonstrating that the planet must be very old—old enough to allow extremely slow organic change. Lyell dismissed the notion of catastrophic extinction of animal forms on a world-wide scale as impossible, and he made plain that natural forces—the work of wind and frost and water—were sufficient to explain most of

the phenomena found in the rocks, provided these forces were seen as operating over enormous periods. Without Lyell's gift of time in immense quantities, Darwin would not have been able to devise the theory of natural selection.

If all the essential elements of the Darwinian scheme of nature were known prior to Darwin, why is he accorded so important a place in biological history? The answer is simple: Almost every great scientific generalization is a supreme act of creative synthesis. There comes a time when an accumulation of smaller discoveries and observations can be combined in some great and comprehensive view of nature. At this point the need is not so much for increased numbers of facts as for a mind of great insight capable of taking the assembled information and rendering it intelligible. Such a synthesis represents the scientific mind at its highest point of achievement. The stature of the discoverer is not diminished by the fact that he has slid into place the last piece of a tremendous puzzle on which many others have worked. To finish the task he must see correctly over a vast and diverse array of data.

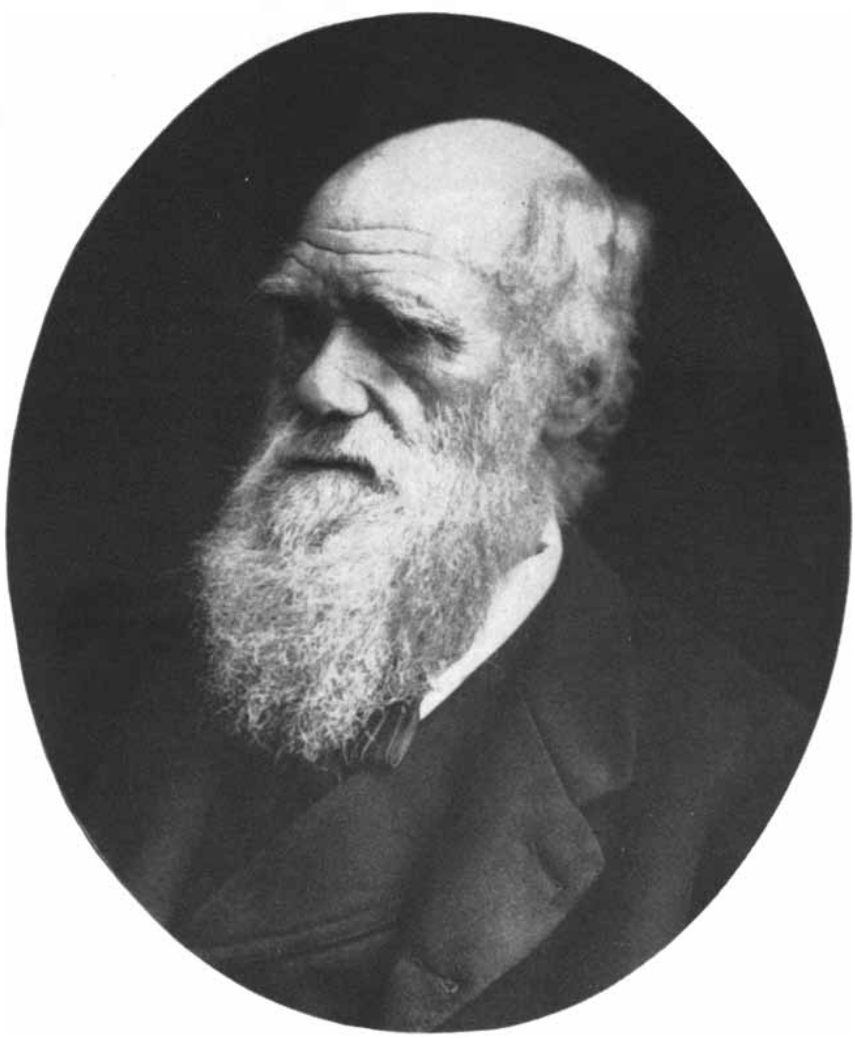
Still it must be recognized that Darwin came at a fortunate time. The fact that another man, Alfred Russel Wallace, conceived the Darwinian theory independently before Darwin published it shows clearly that the principle which came to be called natural selection was in the air—was in a sense demanding to be born. Darwin himself pointed out in his autobiography that "innumerable well-observed facts were stored in the minds of naturalists ready to take their proper places as soon as any theory which would receive them was sufficiently explained."

The Voyage

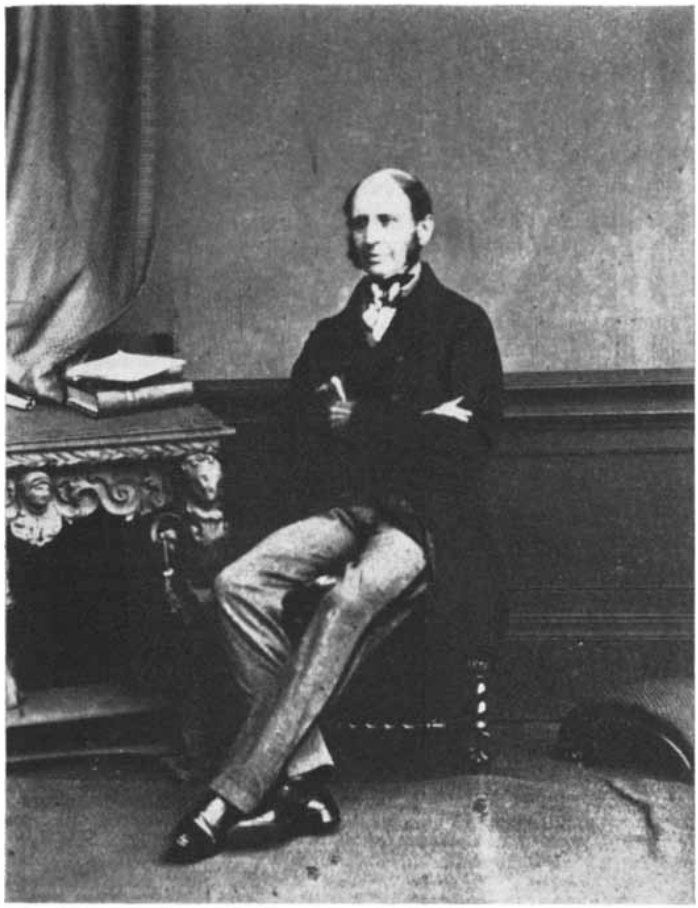
Darwin, then, set out on his voyage with a mind both inquisitive to see and receptive to what he saw. No detail was too small to be fascinating and provocative. Sailing down the South American coast, he notes the octopus changing its color angrily in the waters of a cove. In the dry arroyos of the pampas he observes great bones and shrewdly seeks to relate them to animals of the present. The local inhabitants insist that the fossil bones grew after death, and also that certain rivers have the power of "changing small bones into large." Everywhere men wonder, but they are deceived through their thirst for easy explanations. Darwin, by contrast, is a working dreamer. He rides, climbs, spends long days on the Indian-haunted pampas in constant peril of his life. Asking at a house whether robbers are numerous, he receives the cryptic reply: "The thistles are not up yet." The huge thistles, high as a horse's back at their full growth, provide ecological cover for bandits. Darwin notes the fact and rides on. The thistles are overrunning the pampas; the whole aspect of the vegetation is altering under the impact of man. Wild dogs howl in the brakes; the common cat, run wild, has grown large and fierce. All is struggle, mutability, change. Staring into the face of an evil relative of the rattlesnake, he observes a fact "which appears to me very curious and instructive, as showing how every character, even though it may be in some degree independent of structure . . . has a tendency to vary by slow degrees."

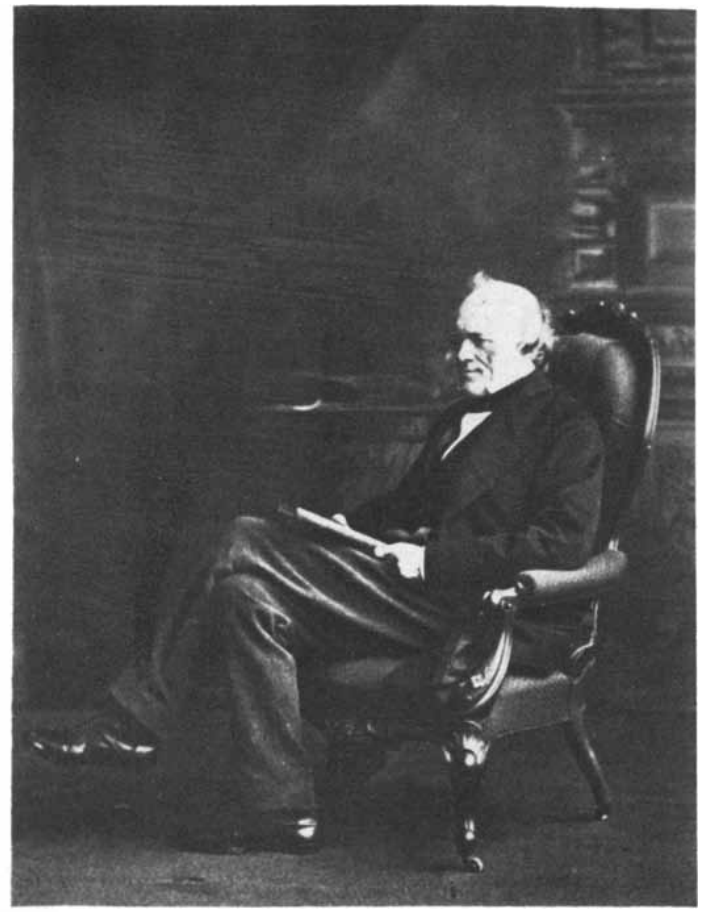
He pays great attention to strange animals existing in difficult environments. A queer little toad with a scarlet belly he whimsically nicknames *diabolicus* because it is "a fit toad to preach in the ear of Eve." He notes it lives among sand dunes under the burning sun, and unlike its brethren, cannot swim. From toads to grasshoppers, from pebbles to mountain ranges, nothing escapes his attention. The wearing away of stone, the downstream travel of rock fragments and boulders, the great crevices and upthrusts of the Andes, an earthquake—all confirm the dynamic character of the earth and its great age.

Captain Fitzroy by now is anxious to voyage on. The sails are set. With the towering Andes on their right flank they run north for the Galápagos Islands, lying directly on the Equator 600 miles off the west coast of South America. A one-time refuge of buccaneers, these islands are essentially chimneys of burned-out volcanoes. Darwin remarks that they



PHOTOGRAPHIC PORTRAIT of Darwin was made some years after the appearance of *Origin of Species*. It is from the collection of George Eastman House in Rochester, N. Y.





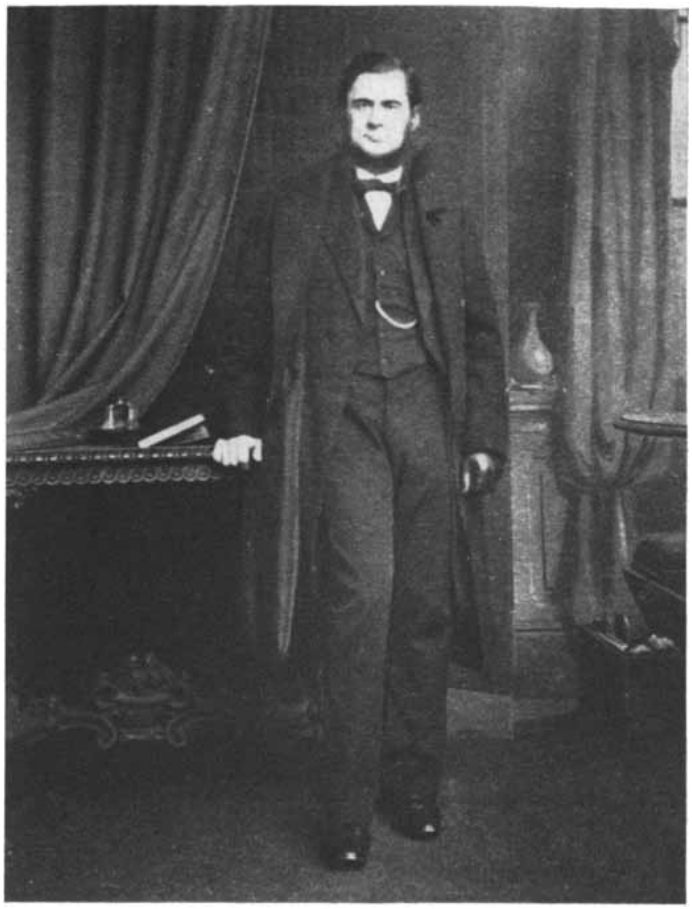
THREE IMPORTANT FIGURES in the life of Darwin appear in *Portraits of Men of Eminence*, three volumes of which were published between 1863 and 1865. This book is also from George Eastman House. At left is Robert Fitzroy, captain of the *Beagle*. Second

remind him of huge iron foundries surrounded by piles of waste. "A little world in itself," he marvels, "with inhabitants such as are found nowhere else." Giant armored tortoises clank through the undergrowth like prehistoric monsters, feeding upon the cacti. Birds in this tiny Eden do not fear men: "One day a mocking bird alighted on the edge of a pitcher which I held in my hand. It began very quietly to sip the water, and allowed me to lift it with the vessel from the ground." Big sea lizards three feet long drowse on the beaches, and feed, fantastically, upon the seaweed. Surveying these "imps of darkness, black as the porous rocks over which they crawl," Darwin is led to comment that "there is no other quarter of the world, where this order replaces the herbivorous mammalia in so extraordinary a manner."

Yet only by degrees did Darwin awake to the fact that he had stumbled by chance into one of the most marvelous evolutionary laboratories on the planet. Here in the Galápagos was a wealth of variations from island to island—among the big tortoises, among plants and especially among the famous finches with remarkably diverse beaks. Dwellers on the islands, notably Vice Governor Lawson, called Darwin's attention to these strange variations, but as he confessed later, with typical Darwinian lack of pretense, "I did not for some time pay sufficient attention to this statement." Whether his visit to the Galápagos was the single event that mainly led Darwin to the central conceptions of his evolutionary mechanism—hereditary change within the organism coupled with external selective factors which might cause plants and animals a few miles apart in the same climate to diverge—is a moot point upon which Darwin himself in later years shed no clear light. Perhaps, like many great men, nagged long after the event for a precise account of the dawn of a great discovery, Darwin no longer clearly remembered the beginning of the intellectual journey which had paralleled so dramatically his passage on the seven seas. Perhaps there had never been a clear beginning at all—only a slowly widening comprehension until what had been seen at first mistily and through a veil grew magnified and clear.

The Invalid and the Book

The paths to greatness are tricky and diverse. Sometimes a man's weaknesses have as much to do with his rise as his virtues. In Darwin's case it proved to be a unique combination of both. He had gathered his material by a courageous and indefatigable pursuit of knowledge that took him through the long vicissitudes of a voyage around the world. But his great work was written in sickness and seclusion. When Darwin reached home after the voyage of the *Beagle*, he was an ailing man, and he remained so to the end of his life. Today we know that this illness was in some degree psychosomatic, that he was anxiety-ridden, subject to mysterious headaches and nausea. Shortly after his voyage Darwin married his cousin Emma Wedgwood, granddaughter of the founder of the great pottery works, and isolated himself and his family in a little village in Kent. He avoided travel like the plague,



is Charles Lyell, the geologist who was Darwin's lifelong confidant. Third is Thomas Huxley, who defended Darwin in debate.

save for brief trips to watering places for his health. His seclusion became his strength and protected him; his very fears and doubts of himself resulted in the organization of that enormous battery of facts which documented the theory of evolution as it had never been documented before.

Let us examine the way in which Darwin developed his great theory. The nature of his observations has already been indicated—the bird beaks, the recognition of variation and so on. But it is an easier thing to perceive that evolution has come about than to identify the mechanism involved in it. For a long time this problem frustrated Darwin. He was not satisfied with vague references to climatic influence or the inheritance of acquired characters. Finally he reached the conclusion that since variation in individual characteristics existed among the members of any species, selection of some individuals and elimination of others must be the key to organic change.

This idea he got from the common recognition of the importance of selective breeding in the improvement of domestic plants and livestock. He still did not understand, however, what selective force could be at work in wild nature. Then in 1838 he chanced to read Thomas Malthus, and the solution came to him. Malthus had written in 1798 a widely read population study in which he pointed out that the human population tended to increase faster than its food supply, precipitating in consequence a struggle for existence.

Darwin applied this principle to the whole world of organic life and argued that the struggle for existence under changing environmental conditions was what induced alterations in the physical structure of organisms. To put it in other words, fortuitous and random variations occurred in living things. The struggle for life perpetuated advantageous variations by means of heredity. The weak and unfit were eliminated and those with the best heredity for any given environment were "selected" to be the parents of the next generation. Since neither life nor climate nor geology ever ceased changing, evolution was perpetual. No organ and no animal was ever in complete equilibrium with its surroundings.

This, briefly stated, is the crux of the Darwinian argument. Facts which had been known before Darwin but had not been recognized as parts of a single scheme—variation, inheritance of variation, selective breeding of domestic plants and animals, the struggle for existence—all suddenly fell into place as "natural selection," as "Darwinism."

Procrastination

While he developed his theory and marshaled his data, Darwin remained in seclusion and retreat, hoarding the secret of his discovery. For 22 years after the *Beagle*'s return he published not one word beyond the bare journal of his trip (later titled *A Naturalist's Voyage around the World*) and technical monographs on his observations.

Let us not be misled, however, by Darwin's seclusiveness and illness. No more lovable or sweet-tempered invalid ever lived. Visitors, however beloved, always aggravated his illness, but instead of the surly misanthropy which afflicts most people under similar circumstances, the result in Darwin's case was merely nights of sleeplessness. Throughout the long night hours his restless mind went on working with deep concentration; more than once, walking alone in the dark hours of winter, he met the foxes trotting home at dawn.

Darwin's gardener is said to have responded once to a visitor who inquired about his master's health: "Poor man, he just stands and stares at a yellow flower for minutes at a time. He would be better off with something to do." Darwin's work was of an intangible nature which eluded people around him. Much of it consisted in just such standing and staring as his gardener reported. It was a kind of magic at which he excelled. On a visit to the Isle of Wight he watched thistle seed wafted about on offshore winds and formulated theories of plant dispersal. Sometimes he engaged in activities which his good wife must surely have struggled to keep from reaching the neighbors. When a friend sent him a half ounce of locust dung from Africa, Darwin triumphantly grew seven plants from the specimen. "There is no error," he assured Lyell, "for I dissected the seeds out of the middle of the pellets." To discover how plant seeds traveled, Darwin would go all the way down a grasshopper's gullet, or worse, without embarrassment. His eldest son Francis spoke amusedly of his father's botanical experiments: "I think he personified each seed as a small demon trying to elude him by getting into the wrong heap, or jumping away all together; and this gave to the work the excitement of a game."

The point of his game Darwin kept largely to himself, waiting until it should be completely finished. He piled up vast stores of data and dreamed of presenting his evolution theory in a definitive, monumental book, so large that it would certainly have fallen dead and unreadable from the press. In the meantime, Robert Chambers, a bookseller and journalist, wrote and brought out anonymously a modified version of Lamarckian evolution, under the title *Vestiges of the*

Natural History of Creation. Amateurish in some degree, the book drew savage onslaughts from the critics, including Thomas Huxley, but it caught the public fancy and was widely read. It passed through numerous editions both in England and America—evidence that *sub rosa* there was a good deal more interest on the part of the public in the "development hypothesis," as evolution was then called, than the fulminations of critics would have suggested.

Throughout this period Darwin remained stonily silent. Many explanations of his silence have been ventured by his biographers: that he was busy accumulating materials; that he did not wish to affront Fitzroy; that the attack on the *Vestiges* had intimidated him; that he thought it wise not to write upon so controversial a subject until he had first acquired a reputation as a professional naturalist of the first rank. Primarily, however, the basic reason lay in his personality—a nature reluctant to face the storm that publication would bring about his ears. It was pleasanter to procrastinate, to talk of the secret to a few chosen companions such as Lyell and the great botanist Joseph Hooker.

The Darwin family had been well-to-do since the time of grandfather Erasmus. Charles was independent, in a position to devote all his energies to research and under no academic pressure to publish in haste.

"You will be anticipated," Lyell warned him. "You had better publish." That was in the spring of 1856. Darwin promised, but again delayed. We know that he left instructions for his wife to see to the publication of his notes in the event of his death. It was almost as if present fame or notoriety were more than he could bear. At all events he continued to delay, and this situation might very well have continued to the end of his life, had not Lyell's warning suddenly come true and broken his pleasant dream.

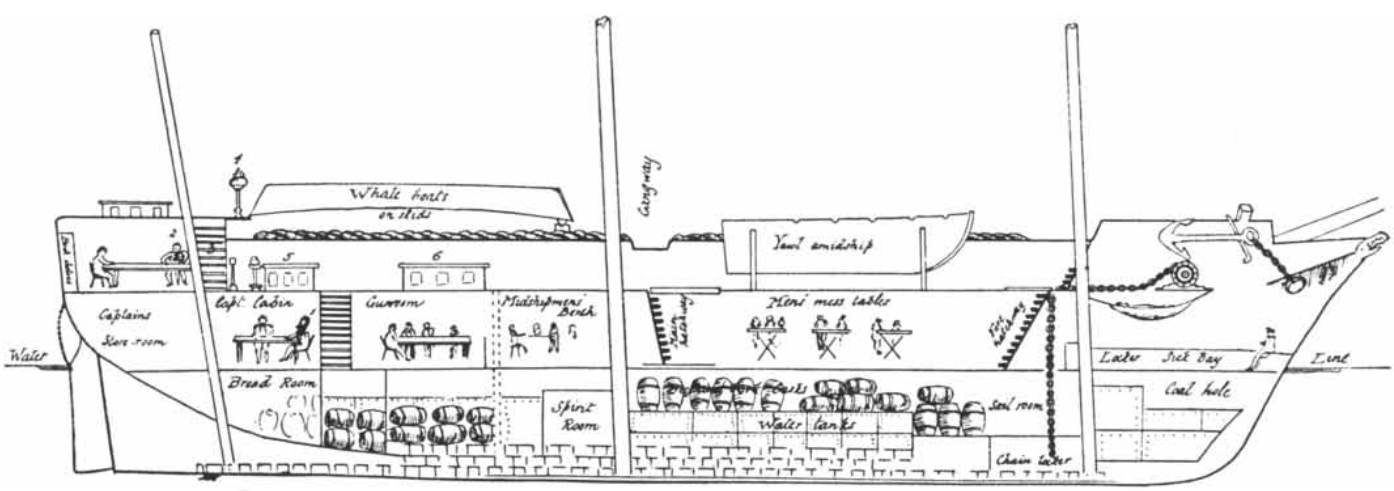
Alfred Russel Wallace, a comparatively unknown, youthful naturalist, had divined Darwin's great secret in a moment of fever-ridden insight while on a collecting trip in Indonesia. He, too, had put together the pieces and gained a clear conception of the scheme of evolution. Ironically enough, it was to Darwin, in all innocence, that he sent his manuscript for criticism in June of 1858. He sensed in Darwin a sympathetic and traveled listener.

Darwin was understandably shaken. The work which had been so close to his heart, the dream to which he had devoted 20 years, was a private secret no longer. A newcomer threatened his priority. Yet Darwin, wanting to do what was decent and ethical, had been placed in an awkward position by the communication. His first impulse was to withdraw totally in favor of Wallace. "I would far rather burn my whole book," he insisted, "than that he or any other man should think that I had behaved in a paltry spirit." It is fortunate for science that before pursuing this quixotic course Darwin turned to his friends Lyell and Hooker, who knew the many years he had been laboring upon his *magnum opus.* The two distinguished scientists arranged for the delivery of a short summary by Darwin to accompany Wallace's paper before the Linnaean Society. Thus the theory of the two men was announced simultaneously.

Publication

The papers drew little comment at the meeting but set in motion a mild undercurrent of excitement. Darwin, though upset by the death of his son Charles, went to work to explain his views more fully in a book. Ironically he called it *An Abstract of an Essay on the Origin of Species* and insisted it would be only a kind of preview of a much larger work. Anxiety and devotion to his great hoard of data still possessed him. He did not like to put all his hopes in this volume, which must now be written at top speed. He bolstered himself by references to the "real" book—that Utopian volume in which all that could not be made clear in his abstract would be clarified.

His timidity and his fears were totally groundless. When the *Origin of Species* (the title distilled by his astute publisher from Darwin's cumbersome and half-hearted one) was published in the fall of 1859, the first edition was sold in a single day. The book which Darwin had so apologetically bowed into existence was, of course, soon to be recognized as one of the great books of all time. It would not be long before its author would sigh happily and think no more of that huge, ideal volume which he had imagined would be necessary to convince the public. The public and his brother scientists would find the *Origin* quite heavy going enough. His book to end all books would never be written. It did not need to be. The world of



H. M. S. BEAGLE was drawn in cross section many years after the voyage by Philip Gidley King, who accompanied Darwin when he was ashore during the voyage. Darwin is shown in two places: the captain's cabin (*small figure 1 at upper left*) and poop cabin (*2*).

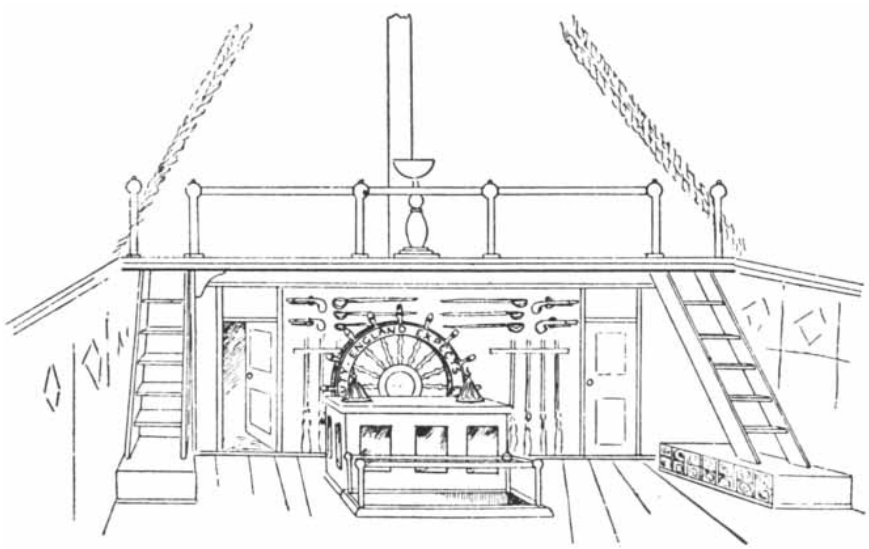
science in the end could only agree with the sharp-minded Huxley, whose immediate reaction upon reading the *Origin* was: "How extremely stupid not to have thought of that!" And so it frequently seems in science, once the great synthesizer has done his work. The ideas were not new, but the synthesis was. Men would never again look upon the world in the same manner as before.

No great philosophic conception ever entered the world more fortunately. Though it is customary to emphasize the religious and scientific storm the book aroused—epitomized by the famous debate at Oxford between Bishop Wilberforce and Thomas Huxley—the truth is that Darwinism found relatively easy acceptance among scientists and most of the public. The way had been prepared by the long labors of Lyell and the wide popularity of Chambers' book, the *Vestiges*. Moreover, Darwin had won the support of the great Hooker and of Huxley, the most formidable scientific debater of all time. Lyell, though more cautious, helped to publicize Darwin and at no time attacked him. Asa Gray, one of America's leading botanists, came to his defense. His codiscoverer, Wallace, as generous-hearted as Darwin, himself advanced the word "Darwinism" for Darwin's theory, and minimized his own part in the elaboration of the theory as "one week to 20 years."

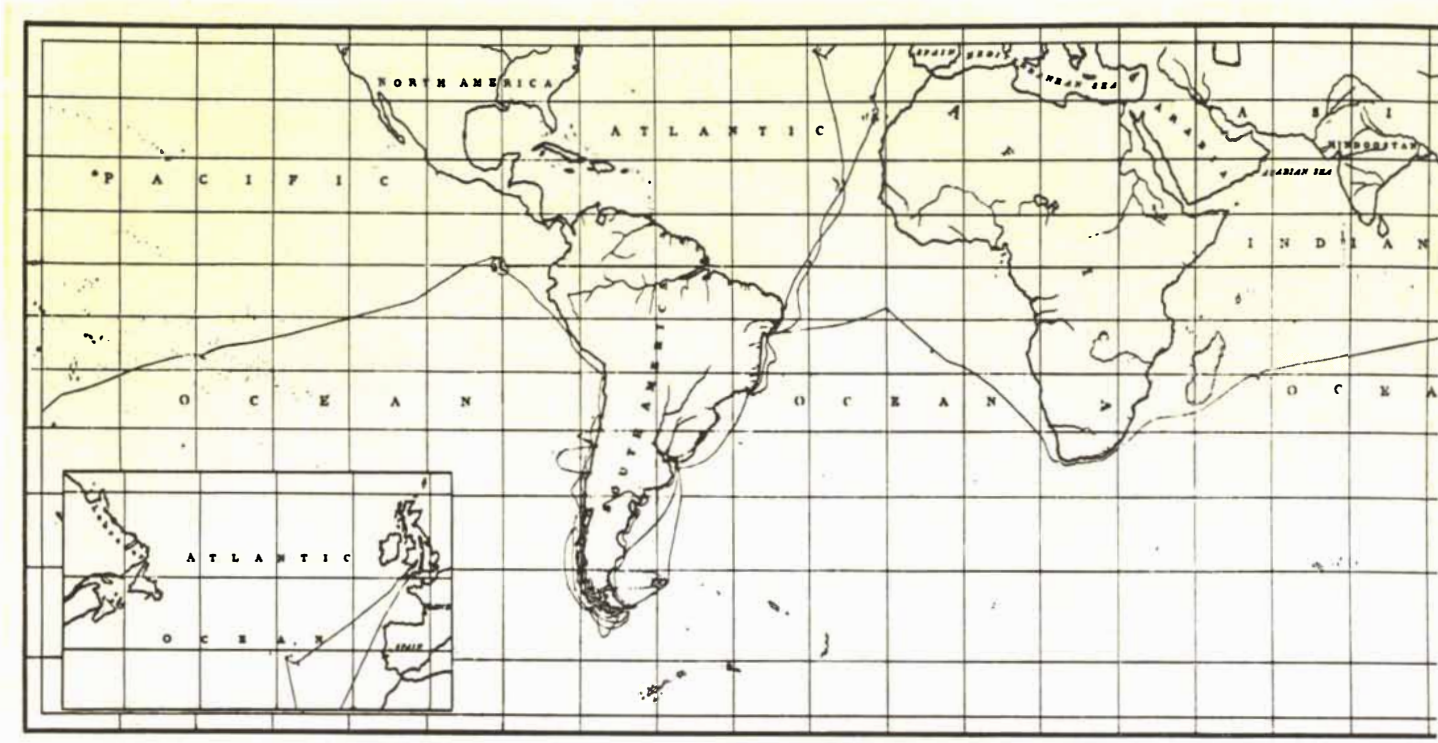
This sturdy band of converts assumed the defense of Darwin before the public, while Charles remained aloof. Sequestered in his estate at Down, he calmly answered letters and listened, but not too much, to the tumult over the horizon. "It is something unintelligible to me how anyone can argue in public like orators do," he confessed to Hooker, though he was deeply grateful for the verbal swordplay of his cohorts. Hewett Watson, another botanist of note, wrote to him shortly after the publication of the *Origin:* "Your leading idea will assuredly become recognized as an established truth in science, *i.e.*, 'Natural Selection.' It has the characteristics of all great natural truths, clarifying what was obscure, simplifying what was intricate, adding greatly to previous knowledge. You are the greatest revolutionist in natural history of this century, if not of all centuries."

Watson's statement was clairvoyant. Not a line of his appraisal would need to be altered today. Within 10 years the *Origin* and its author were known all over the globe, and evolution had become the guiding motif in all biological studies.

Summing up the achievement of this book, we may say today, first, that Darwin had proved the reality of evolutionary change beyond any reasonable doubt, and secondly, that he had demonstrated, in natural selection, a principle capable of wide, if not universal, application. Natural selection dispelled the confusions that had been introduced into biology by the notion of individual creation of species. The lad who in 1832 had noted with excited interest "that there are three sorts of birds which use their wings for more purposes than flying; the Steamer [duck] as paddles, the Penguin as fins, and the Ostrich (*Rhea*) spreads its plumes like sails" now had his answer—"descent with modification." "If you go any considerable lengths in the



QUARTER-DECK of the *Beagle* is depicted in this drawing by King. In the center is the wheel, the circumference of which is inscribed: "England expects every man to do his duty."



VOYAGE OF THE BEAGLE is traced in this map from Fitzroy's *Narrative of the Surveying Voyage of His Majesty's Ships Adventure and Beagle.* The *Beagle*'s course on her departure from and return to England is at lower left. The ship made frequent stops at

admission of modification," warned Darwin, "I can see no possible means of drawing the line, and saying here you must stop." Rung by rung, was his plain implication, one was forced to descend down the full length of life's mysterious ladder until one stood in the brewing vats where the thing was made. And similarly, rung by rung, from mudfish to reptile and mammal, the process ascended to man.

A Small Place for Man

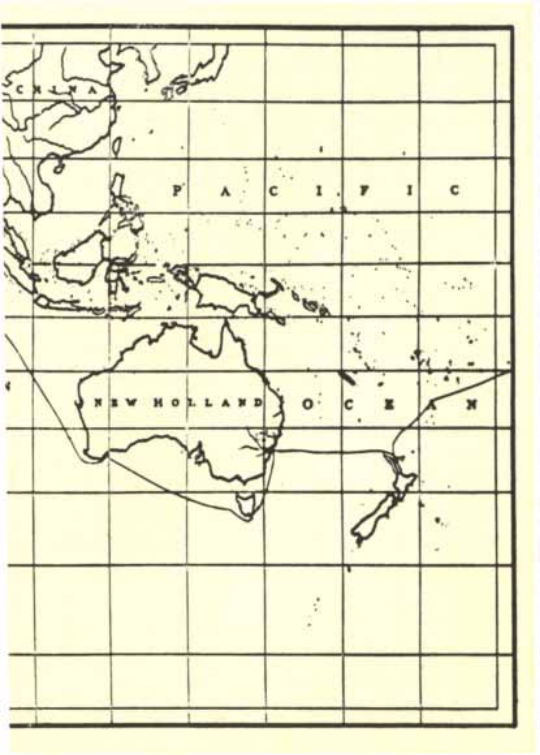
Darwin had cautiously avoided direct references to man in the *Origin of Species.* But 12 years later, after its triumph was assured, he published a study of human evolution entitled *The Descent of Man.* He had been preceded in this field by Huxley's *Evidences as to Man's Place in Nature* (1863). Huxley's brief work was written with wonderful clarity and directness. By contrast, the *Descent of Man* has some of the labored and inchoate quality of Darwin's overfull folios of data. It is contradictory in spots, as though the author simply poured his notes together and never fully read the completed manuscript to make sure it was an organic whole.

One of its defects is Darwin's failure to distinguish consistently between biological inheritance and cultural influences upon the behavior and evolution of human beings. In this, of course, Darwin was making a mistake common to biologists of the time. Anthropology was then in its infancy. In the biological realm, the *Descent of Man* did make plain in a general way that man was related to the rest of the primate order, though the precise relationship was left ambiguous. After all, we must remember that no one had yet unearthed any clear fossils of early man. A student of evolution had to content himself largely with tracing morphological similarities between living man and the great apes. This left considerable room for speculation as to the precise nature of the human ancestors. It is not surprising that they were occasionally visualized as gorilloid beasts with huge canine teeth, nor that Darwin wavered between this and gentler interpretations.

An honest biographer must record the fact that man was not Darwin's best subject. In the words of a 19th-century critic, his "was a world of insects and pigeons, apes and curious plants, but man as he exists, had no place in it." Allowing for the hyperbole of this religious opponent, it is nonetheless probable that Darwin did derive more sheer delight from writing his book on earthworms than from any amount of contemplation of a creature who could talk back and who was apt stubbornly to hold ill-founded opinions. In any case, no man afflicted with a weak stomach and insomnia has any business investigating his own kind. At least it is best to wait until they have undergone the petrification incident to becoming part of a geological stratum.

Darwin knew this. He had fled London to work in peace. When he dealt with the timid gropings of climbing plants, the intricacies of orchids or the calculated malice of the carnivorous sundew, he was not bedeviled by metaphysicians, by talk of ethics, morals or the nature of religion. Darwin did not wish to leave man an exception to his system, but he was content to consider man simply as a part of that vast, sprawling, endlessly ramifying ferment called "life." The rest of him could be left to the philosophers. "I have often," he once complained to a friend, "been made wroth (even by Lyell) at the confidence with which people speak of the introduction of man, as if they had seen him walk on the stage and as if in a geological sense it was more important than the entry of any other mammifer."

Darwin's fame as the author of the theory of evolution has tended to ob-



oceanic islands. The Galápagos Islands are on the Equator to the west of South America.

scure the fact that he was, without doubt, one of the great field naturalists of all time. His capacity to see deep problems in simple objects is nowhere better illustrated than in his study of movement in plants, published some two years before his death. He subjected twining plants, previously little studied, to a series of ingenious investigations of pioneer importance in experimental botany. Perhaps Darwin's intuitive comparison of plants to animals accounted for much of his success in this field. There is an entertaining story that illustrates how much more perceptive than his contemporaries he was here. To Huxley and another visitor, Darwin was trying to explain the remarkable behavior of *Drosera*, the sundew plant, which catches insects with grasping, sticky hairs. The two visitors listened to Darwin as one might listen politely to a friend who is slightly "touched." But as they watched the plant, their tolerant poise suddenly vanished and Huxley cried out in amazement: "Look, it *is* moving!"

The Islands

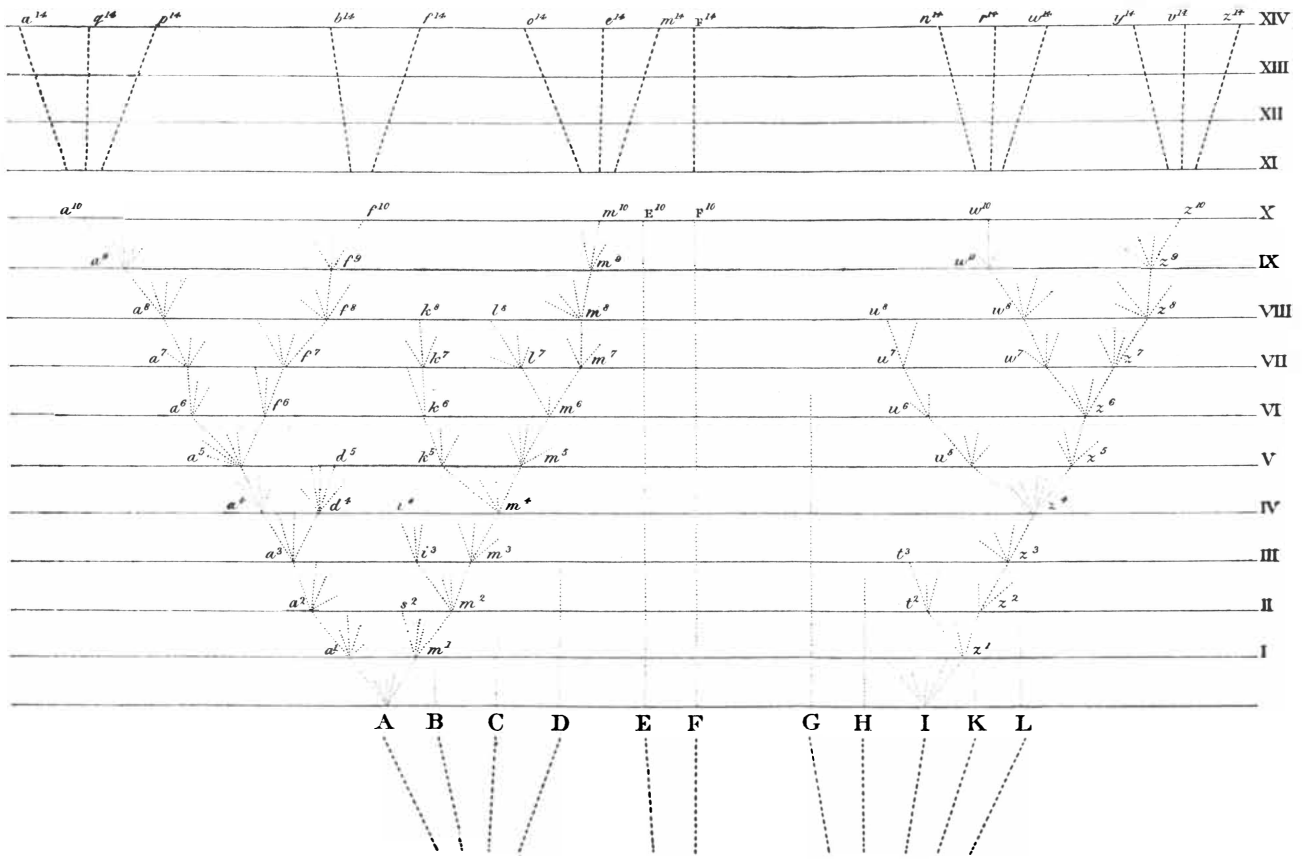
As one surveys the long and tangled course that led to Darwin's great discovery, one cannot but be struck by the

part played in it by oceanic islands. It is a part little considered by the general public today. The word "evolution" is commonly supposed to stand for something that occurred in the past, something involving fossil apes and dinosaurs, something pecked out of the rocks of eroding mountains—a history of the world largely demonstrated and proved by the bone hunter. Yet, paradoxically, in Darwin's time it was this very history that most cogently challenged the evolutionary point of view. Paleontology was not nearly so extensively developed as today, and the record was notable mainly for its gaps. "Where are the links?" the critics used to rail at Darwin. "Where are the links between man and ape—between your lost land animal and the whale? Show us the fossils; prove your case." Darwin could only repeat: "This is the most obvious and gravest objection which can be urged against my theory. The explanation lies, as I believe, in the extreme imperfection of the geological record." The evidence for the continuity of life must be found elsewhere. And it was the oceanic islands that finally supplied the clue.

Until Darwin turned his attention to them, it appears to have been generally assumed that island plants and animals were simply marooned evidences of a past connection with the nearest continent. Darwin, however, noted that whole classes of continental life were absent from the islands; that certain plants which were herbaceous (nonwoody) on the mainland had developed into trees on the islands; that island animals often differed from their counterparts on the mainland.

Above all, the fantastically varied finches of the Galápagos particularly amazed and puzzled him. The finches diverged mainly in their beaks. There were parrot-beaks, curved beaks for probing flowers, straight beaks, small beaks—beaks for every conceivable purpose. These beak variations existed nowhere but on the islands; they must have evolved there. Darwin had early observed: "One might really fancy that, from an original paucity of birds in this archipelago, one species had been taken and modified for different ends." The birds had become transformed, through the struggle for existence on their little islets, into a series of types suited to particular environmental niches where, properly adapted, they could obtain food and survive. As the ornithologist David Lack has remarked: "Darwin's finches form a little world of their own, but one which intimately reflects the world as a whole" [see "Darwin's Finches," by David Lack; SCIENTIFIC AMERICAN, April, 1953].

Darwin's recognition of the significance of this miniature world, where the forces operating to create new beings could be plainly seen, was indispensable to his discovery of the origin of species. The island worlds reduced the confusion of continental life to more simple propor-



NATURAL SELECTION through the divergence of characters is illustrated in *Origin of Species*. The capital letters at the bottom of the illustration represent different species of the same genus. Each horizontal line, labeled with a Roman numeral at the right, represents 1,000 or more generations. Darwin believed that some of the original species, such as A, would diverge more than others. After many generations they would give rise to new varieties, such as a^1 and m^1. These new varieties would diverge in turn. After thousands of generations the new varieties would give rise to entirely new species, such as a^{14}, q^{14}, p^{14} and so on. The original species would meantime have died out. Darwin thought that only some species of the original genus would diverge sufficiently to give rise to new species. Some of the species, such as F, would remain much the same. Others, such as B, C and D, would die out.

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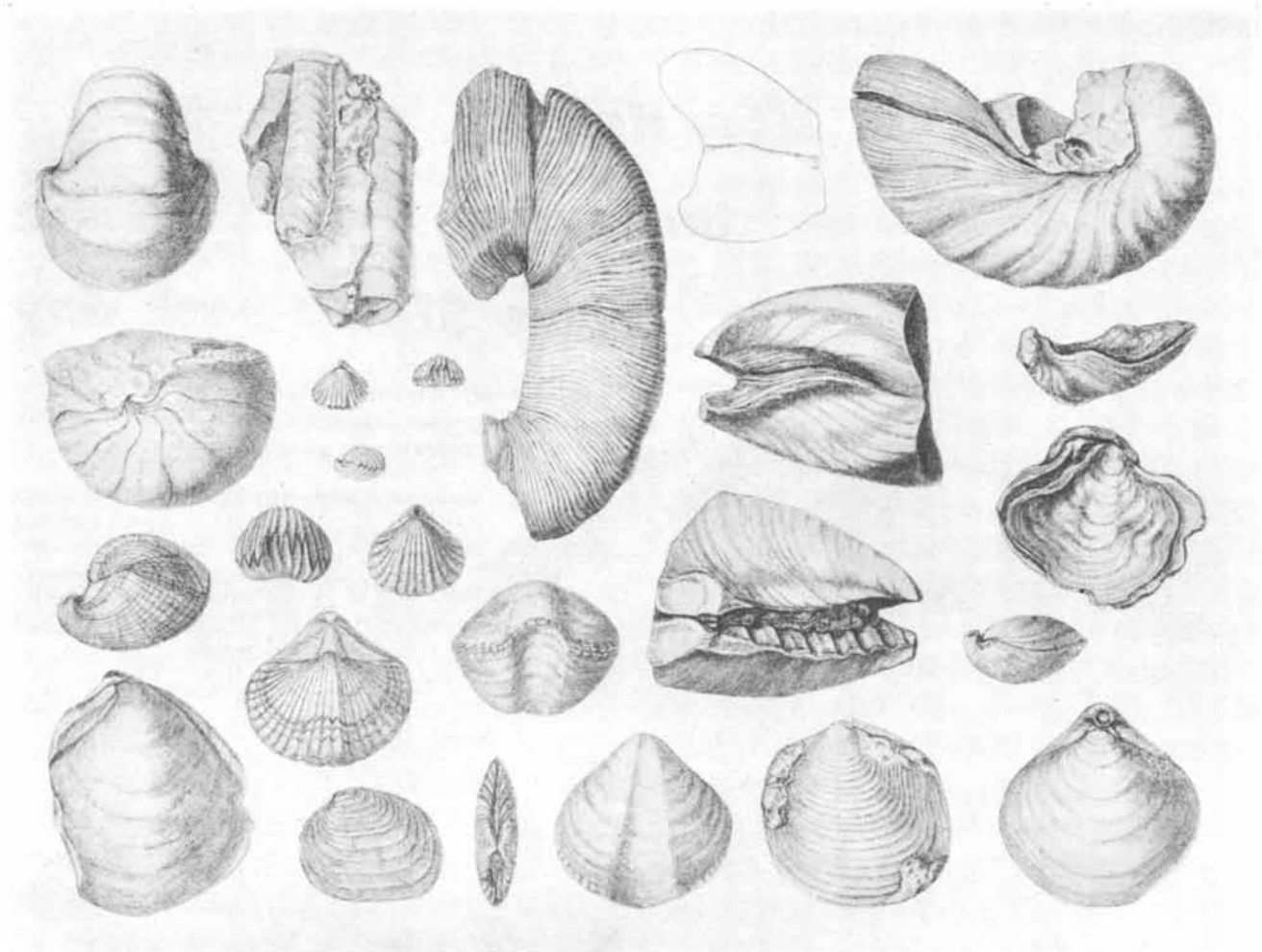

FOSSIL SHELLS were depicted in this engraving from Darwin's *Geological Observations on the Volcanic Islands and Parts of South America Visited during the Voyage of H. M. S. Beagle.* This was a technical work published by Darwin before *Origin of Species.*

tions; one could separate the factors involved with greater success. Over and over Darwin emphasized the importance of islands in his thinking. Nothing would aid natural history more, he contended to Lyell, "than careful collecting and investigating of *all the productions* of the most isolated islands. . . . Every sea shell and insect and plant is of value from such spots."

Darwin was born in precisely the right age even in terms of the great scientific voyages. A little earlier the story the islands had to tell could not have been read; a little later much of it began to be erased. Today all over the globe the populations of these little worlds are vanishing, many without ever having been seriously investigated. Man, breaking into their isolation, has brought with him cats, rats, pigs, goats, weeds and insects from the continents. In the face of these hardier, tougher, more aggressive competitors, the island faunas—the rare, the antique, the strange, the beautiful—are vanishing without a trace. The giant Galápagos tortoises are almost extinct, as is the land lizard with which Darwin played. Some of the odd little finches and rare plants have gone or will go. On the island of Madagascar our own remote relatives, the lemurs, which have radiated into many curious forms, are now being exterminated through the destruction of the forests. Even that continental island Australia is suffering from the decimation wrought by man. The Robinson Crusoe worlds where small castaways could create existences idyllically remote from the ravening slaughter of man and his associates are about to pass away forever. Every such spot is now a potential air base where the cries of birds are drowned in the roar of jets, and the crevices once frequented by bird life are flattened into the long runways of the bombers. All this would not have surprised Darwin, one would guess.

Of Darwin's final thoughts in the last hours of his life in 1882, when he struggled with a weakening heart, no record remains. One cannot but wonder whether this man who had no faith in Paradise may not have seen rising on his dying sight the pounding surf and black slag heaps of the Galápagos, those islands called by Fitzroy "a fit shore for Pandemonium." None would ever see them again as Darwin had seen them—smoldering sullenly under the equatorial sun and crawling with uncertain black reptiles lost from some earlier creation. Once he had cried out suddenly in anguish: "What a book a devil's chaplain might write on the clumsy, wasteful, blundering, low and horribly cruel works of nature!" He never spoke or wrote in quite that way again. It was more characteristic of his mind to dwell on such memories as that Eden-like bird drinking softly from the pitcher held in his hand. When the end came, he remarked with simple dignity, "I am not in the least afraid of death."

It was in that spirit he had ventured upon a great voyage in his youth. It would suffice him for one more journey.

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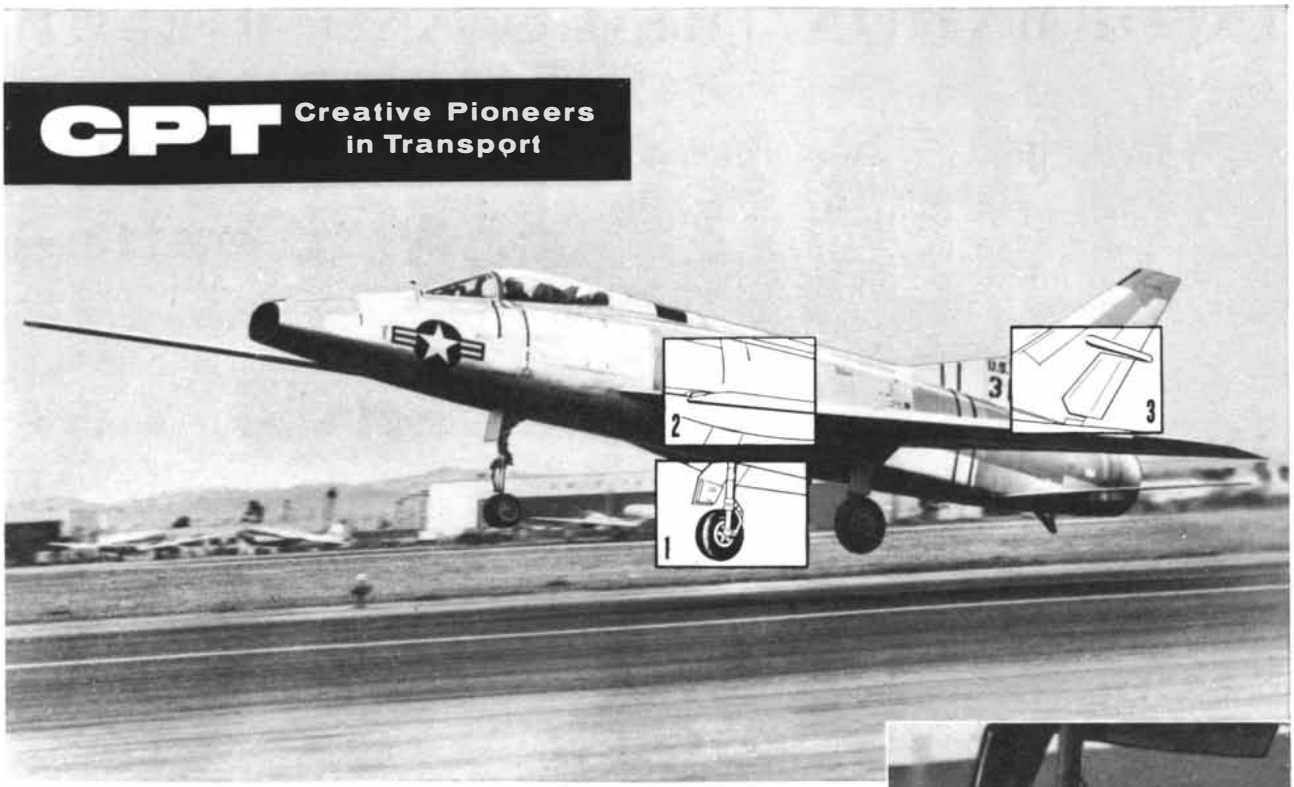

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INFORMATION THEORY AND MELODY

What is it about simple melodies that makes them so widely appealing? By considering music as a form of communication such questions can now be discussed in mathematical terms

by Richard C. Pinkerton

It is perhaps foolhardy to suggest that a machine might write a poem or compose a song. An artist is likely to exclaim indignantly at the very idea, and a scientist can only approach it with caution. The elusive creative processes of the human mind seem to defy analysis, to say nothing of duplication. And yet it can certainly do no harm to try to find what light we can on the subject. It may, indeed, be quite entertaining, as this article will attempt to show by considering an exercise in the analysis of melody.

Music has always attracted investigation by scientists. The experiments of Helmholtz on the pitch and quality of musical tones are classics in the field of physics. They showed how the choice of scales rests on simple physical relations, why certain combinations of notes sound harmonious and others dissonant, and so on.

Helmholtz described a melody as "a variation of pitch in time." Obviously this definition is only a small part of the story. Not every succession of different notes is a melody. What is it, then, that makes certain sequences of notes sound tuneful—that makes eyes light up and sets feet tapping?

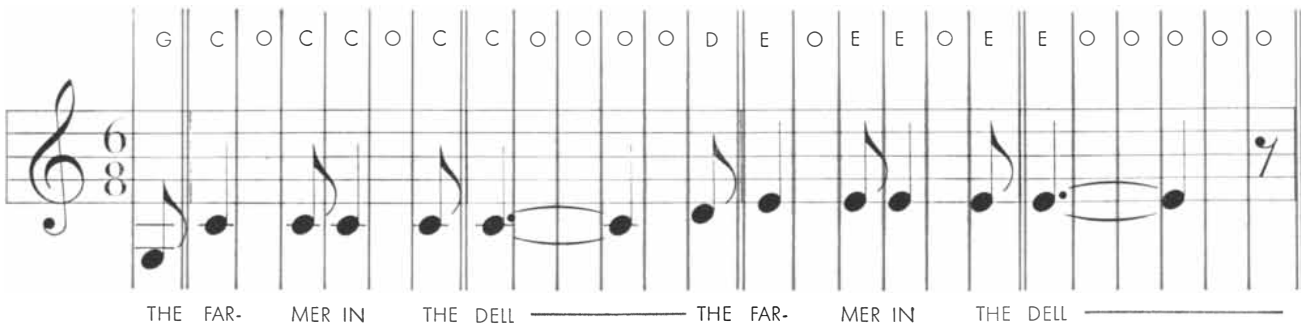
Some years ago the late Joseph Schillinger, who was a teacher of mathematics at Columbia University and also a musician, examined these questions in scientific terms. He was an experimenter who believed that art forms could be analyzed by mathematics and synthesized by "the technique of engineering." Schillinger evolved a mathematical system for composing music, and George Gershwin is said to have used this system while composing *Porgy and Bess*. Our aim in this article is something much less ambitious: we shall consider some simple nursery tunes and try to find the properties that make them tuneful.

Suppose we regard music simply as a form of communication. We can then get a great deal of help from modern communication theory [see "The Mathematics of Communication," by Warren Weaver; SCIENTIFIC AMERICAN, July, 1949]. In this theory a basically important element is the idea of entropy. Many years ago Sir Arthur Eddington observed that entropy should be placed in the same category with beauty and melody. Entropy is a description of the association between the elements in a system; it applies to the notes in a composition as well as to the molecules in a vessel.

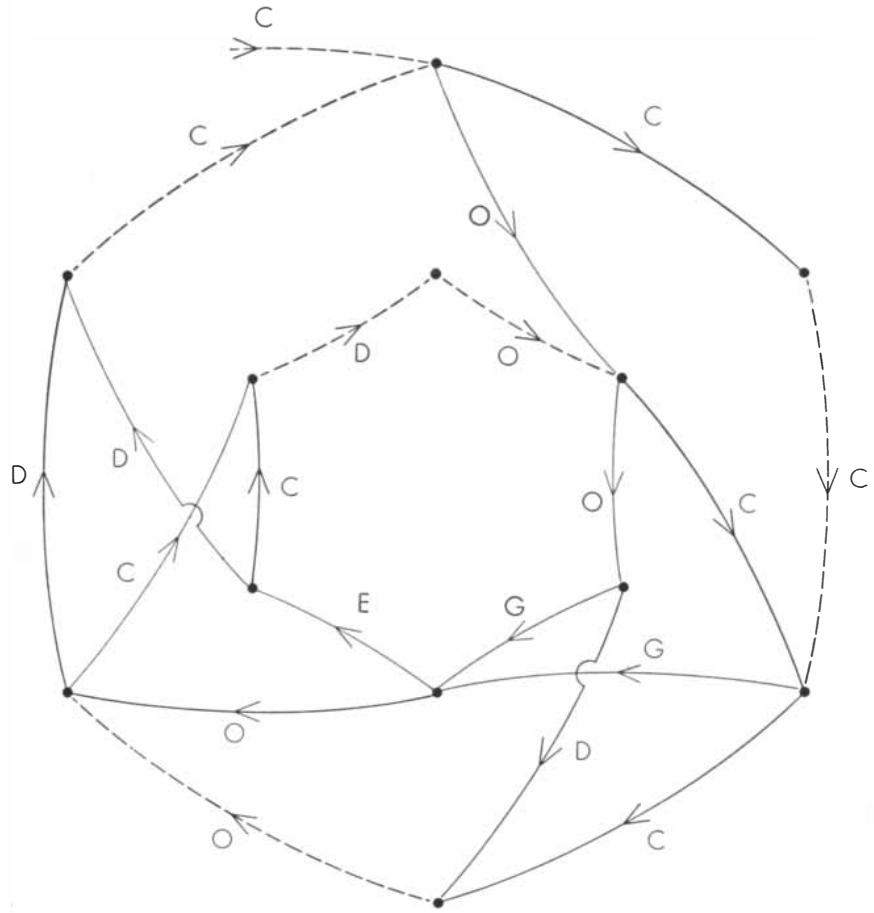
Now entropy is a numerical index of disorder. If we come upon a situation in which there is a high degree of uncertainty, in which everything is mixed up, we may say that the entropy is high. On the other hand, where there is a great deal of symmetry or patterned arrangement, the entropy is low. For example, a well-managed supermarket has low entropy: we are sure to find the canned vegetables grouped in a certain section, the breakfast food in another section, and so on. But in a store where we were equally likely to find the peas stacked with the waxed paper or heaped on the floor with the laundry soap, we would have to say that the entropy was high.

The higher the entropy, the more information can be conveyed. In a disordered store it might take a clerk days to tell us the location of all the items—*i.e.*, to communicate all the information contained in the situation. Similarly a map showing roads running helter-skelter contains more information than a piece of wallpaper with a monotonously repeated pattern.

We may ask: What is the entropy of nursery tunes? There are certain features common to all "whistling tunes." First of all, they have to sound somewhat familiar: some of the sequences



ANALYSIS OF TUNES begins by translating their notes into the usual alphabetical symbols, using "O" to represent a rest or the holdover of a note beyond its initial beat. The colored vertical lines mark off measures (*double lines*) and beats (*single lines*).

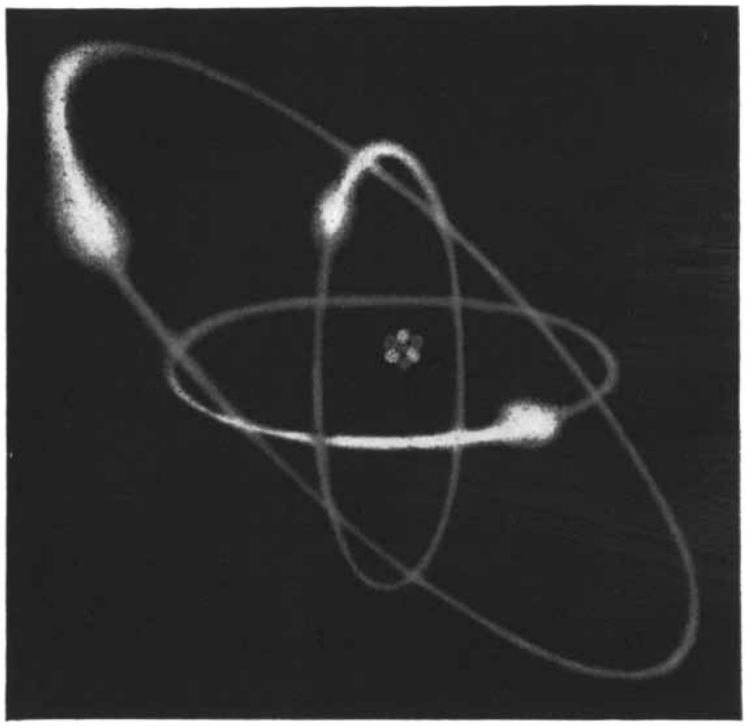


BANAL TUNE-MAKER produces simple, redundant melodies that sound like nursery tunes. A sequence of notes is obtained by following a path through the network, starting at the top, and writing down the note (or rest) attached to each segment traversed. Where there is a choice of paths, a coin is flipped. If it comes up heads, the black path is taken; if tails, the colored path. Broken lines show the path from a junction where there is no choice.

should have been heard before. Secondly, a melody always has certain basic qualities of regularity and symmetry: in terms of communication theory, it is somewhat redundant. Thus the composer of a melody must make the entropy of his music low enough to give it an apparent pattern and at the same time high enough so that it has sufficient complexity to be interesting. The question is, how high should the entropy be, and how can it be measured?

Let us make a statistical analysis of familiar nursery tunes. I selected a representative group of 39 from *The Golden Song Book* by Catherine Tyler Wessells (Simon and Schuster). The first step was to count the frequency with which the various notes of the scale appeared. To simplify matters I put all the songs in the key of C and treated all the notes as if they were in a single octave: thus middle C and C above middle C were both counted simply as C. To the seven different notes of the octave I added an eighth symbol, O, to signify a rest or the holding of a note for more than one beat. The set of eight symbols then is C, D, E, F, G, A, B and O. Translating "The Farmer in the Dell," for example, into this code, we get G/COCCOC/COOOOD/EOEEOE/-EOOOOO/GOOGOA/GOECOD/EO-EDOD/COOOO. (The song is written in 6/8 time and therefore has six beats per measure.) After writing all the 39 songs in this code, I counted the number of times each note appeared, and from this calculated the probability of occurrence for each. The probabilities are: C – .163; D – .112; E – .132; F – .066; G – .149; A – .045; B – .036; O – .297.

These probabilities are, of course, just what a musician would expect from his knowledge of tonal relations. The most pleasing sequences of notes are those in which the pitch, or number of vibrations per second, of the successive notes is related in the ratio of small whole numbers. Since C is our key note, we should expect G to appear fairly frequently, because it is related to C by the ratio 3/2 (*i.e.*, 396 to 264 v.p.s.). On the other



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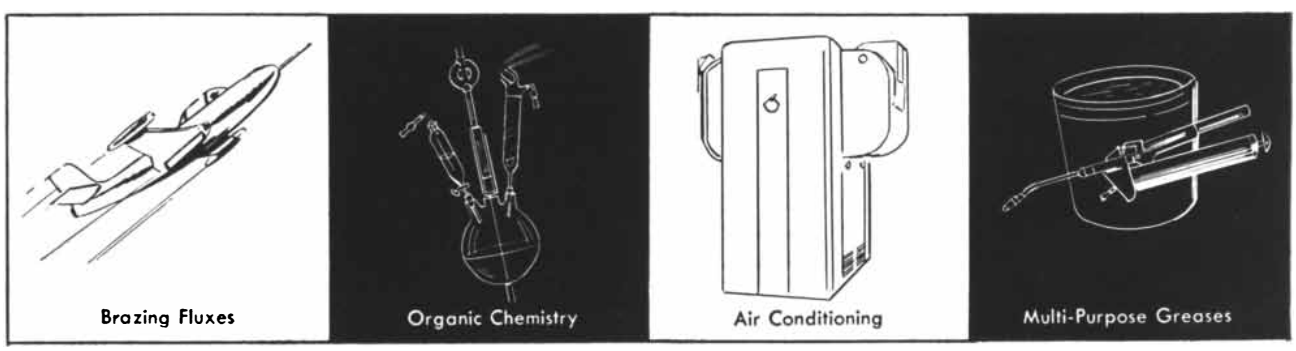

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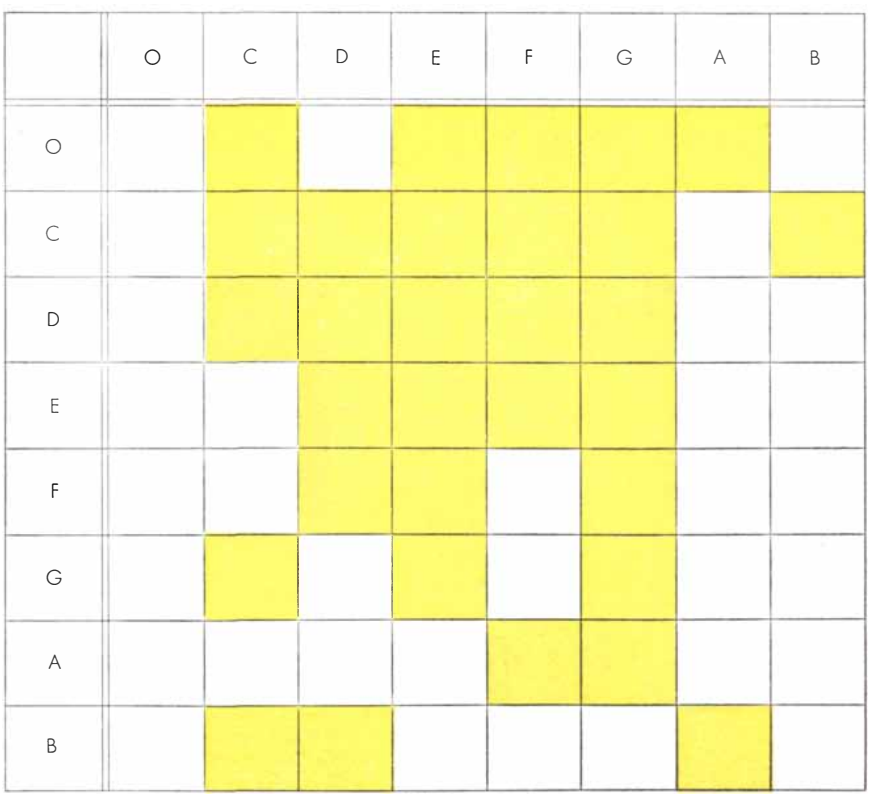
	O	C	D	E	F	G	A	B
O	0.38	0.17	0.10	0.10	0.06	0.13	0.03	0.02
C	0.36	0.23	0.13	0.07	0.02	0.10	0.03	0.07
D	0.26	0.20	0.21	0.19	0.03	0.06	0.01	0.05
E	0.22	0.15	0.18	0.16	0.16	0.12	0.01	0 00
F	0.15	0.00	0.14	0.35	0.14	0.20	0.01	0.01
G	0.29	0.14	0.00	0.16	0.06	0.26	0.08	0.00
A	0.17	0.05	0.07	0.00	0.02	0.36	0.15	0.17
B	0.18	0.30	0.12	0.01	0.01	0.08	0.21	0.08

TRANSITION PROBABILITIES show how frequently any note follows any other in the 39 nursery tunes. The first notes of all possible pairs are listed in the column at the left; the second notes, in the row at the top. Thus each number in the table gives the probability that the note at the top of its column will come after the note at the left of its row. The color pattern divides the table between likely transitions (*colored*) and unlikely (*white*).



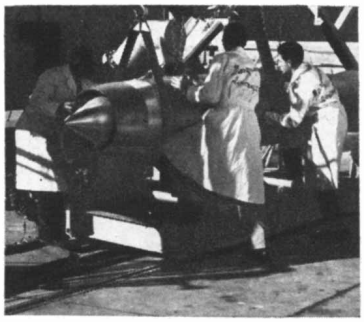
TRANSITION PATTERN CHANGES when account is taken of the position of a note in the measure. This diagram shows the distribution of high (*colored*) and low (*white*) probabilities for the transition from the last note of a measure to the first note of the next.

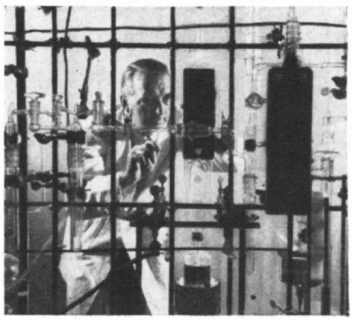
hand, the note B, related to C by the more complex ratio 15/8, should have a lower probability.

Now we go back to our original question: What is the entropy of the nursery tunes? Obviously the situation of maximum entropy would be that in which all notes had an equal probability of occurring. To the degree that the selection of notes departs from complete randomness, the entropy is lowered. As a first approximation, then, we might estimate the entropy of the tunes from the relative frequency of occurrence of the several notes. There is a formula by which we can calculate the entropy per note when the probabilities are known: it is derived from the famous Boltzmann "H" theorem of thermodynamics. By this calculation, the maximum possible entropy for eight notes would be $\log_{10} 8$, or .903. (For convenience I used logarithms to the base 10 rather than the base 2.) According to their actual probability of occurrence in nursery tunes, the entropy of the notes is .821. This would make the entropy 91 per cent of the possible maximum; or, in other terms, the redundancy would be 9 per cent.

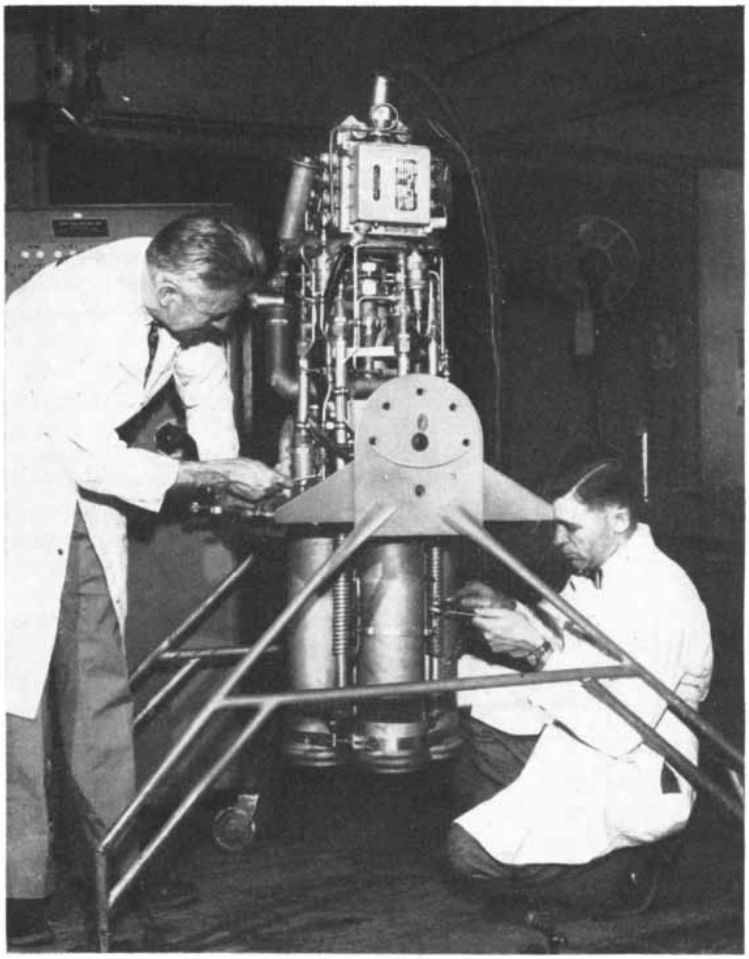
Obviously nursery tunes have a great deal higher redundancy than that. The redundancy of letters in English text is about 50 per cent, and nursery tunes are probably more redundant than our written language. To get an accurate estimate of their redundancy we must do more than merely count the number of times each note appears; we must also consider, among other things, the grouping of notes. Any given note must strongly influence our choice of the next note. For example, because it is easy to strike notes which are next to each other on the piano, adjacent notes have a high probability of following each other; thus once we have struck an F, the probabilities of hitting an E or a G are much higher than before. Again, an F seldom follows a B, because the interval between these two notes (called a diminished fifth) is a difficult one for the human voice to hit accurately.

Taking the same nursery tunes, let us count the number of times specific notes are paired and make a table of these probabilities, or what the mathematicians call a "matrix of transition probabilities" [*see table on page 82*]. Now from this table we can begin to construct melodies, selecting each successive note by a method which weights the choices according to the probabilities. We may use 12 cards to make the choices. Suppose we start with the note C. The probability is about 4/12 that C





NEW TEAM IMPETUS . . .

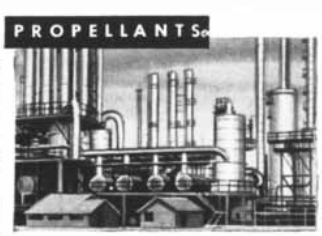


adds power to rocket propulsion

Now, the modern "weapons system" concept is applied to the development and production of rockets, ramjets, and special liquid and solid propellants. Reaction Motors, Marquardt Aircraft, and Olin Mathieson Chemical combine for the first time as part of an integrated plan both chemical and mechanical experience applicable to high-energy power generation. Coordinated by the OMAR Joint Technical Committee comprised of representatives of the three companies, this applied research program is dedicated to the practical advancement of supersonic aircraft and missile propulsion.

First in the American rocket industry, Reaction Motors develops and builds powerplants such as the one above that set a new piloted-aircraft speed record of over 1600 mph in the Air Force Bell X-1A. Working with Marquardt Aircraft and Olin Mathieson Chemical, RMI contributes to a continuous joint technical program to achieve improved rocket and ramjet engines and special fuels.

Marquardt Aircraft Company



Olin Mathieson Chemical Corporation

Reaction Motors, Inc.

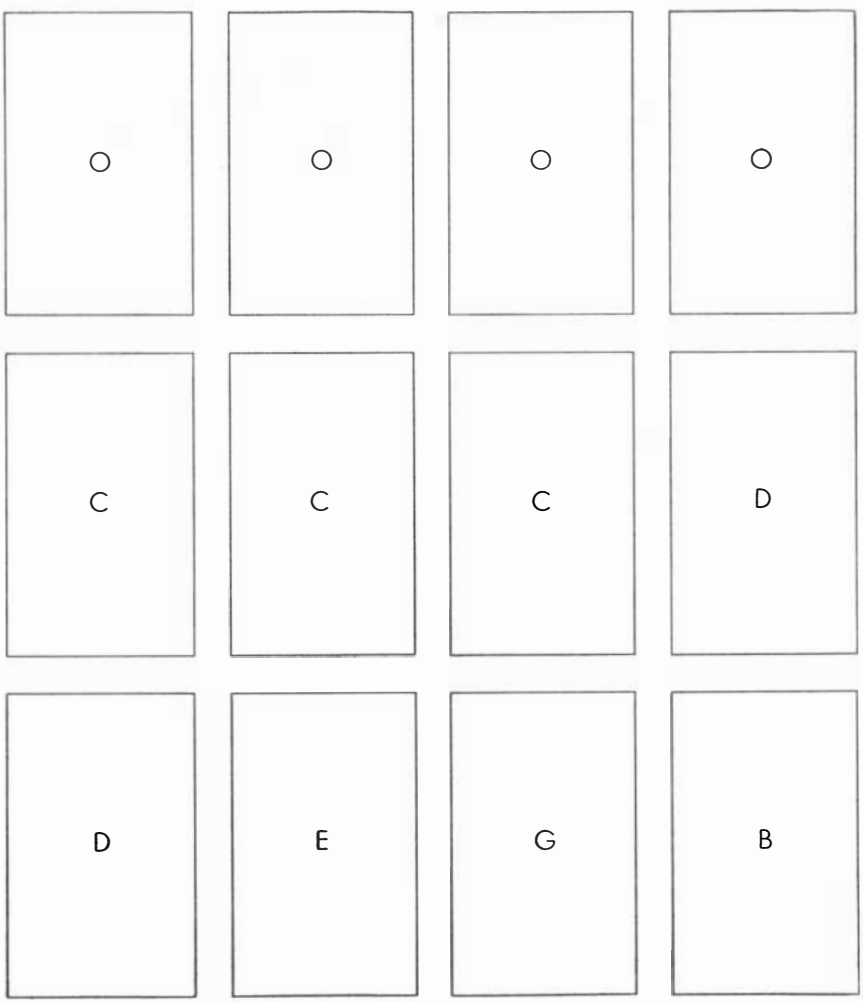
3527

TRANSITION	C-O	C-C	C-D	C-E	C-F	C-G	C-A	C-B
PROBABILITY "p"	0.36	0.23	0.13	0.07	0.02	0.10	0.03	0.07
APPROXIMATE "p"	4/12	3/12	2/12	1/12	0	1/12	0	1/12

TRANSITIONS FROM C are listed above. The upper row of probability values is taken from material in the text. In the lower row, these values have been rounded off to 12ths.

will be followed by a pause, so we mark four cards O. There is a 3/12 probability that the note after C will be another C, so three cards are marked C. Similarly two cards are marked D and one card is marked E, one G and one B. Now we shuffle the 12 cards and draw one to choose the note after C. Say we draw G. We go back to the table, make up another set of cards based on the probabilities of the notes following G and choose our next note by drawing one of these cards. We continue this process until we have composed a sequence.

Now we find we are beginning to get somewhere. Snatches and phrases of the sequence sound quite tuneful. But something important is missing. What we have is a kind of be-bop nursery tune, with peculiar misplacements of emphasis due to erratic distribution of the pauses. They may pop up anywhere, even on the first beat of a measure. To construct a true nursery tune we need more redundancy, in the form of rhythm. In a simple tune pauses (O) are used in a rhythmic sense, and they never occur at the beginning of a measure. So we



NOTE AFTER C can be picked out by means of this set of 12 cards. The number of cards bearing each symbol reflects the probability (in 12ths) that the symbol will follow C.

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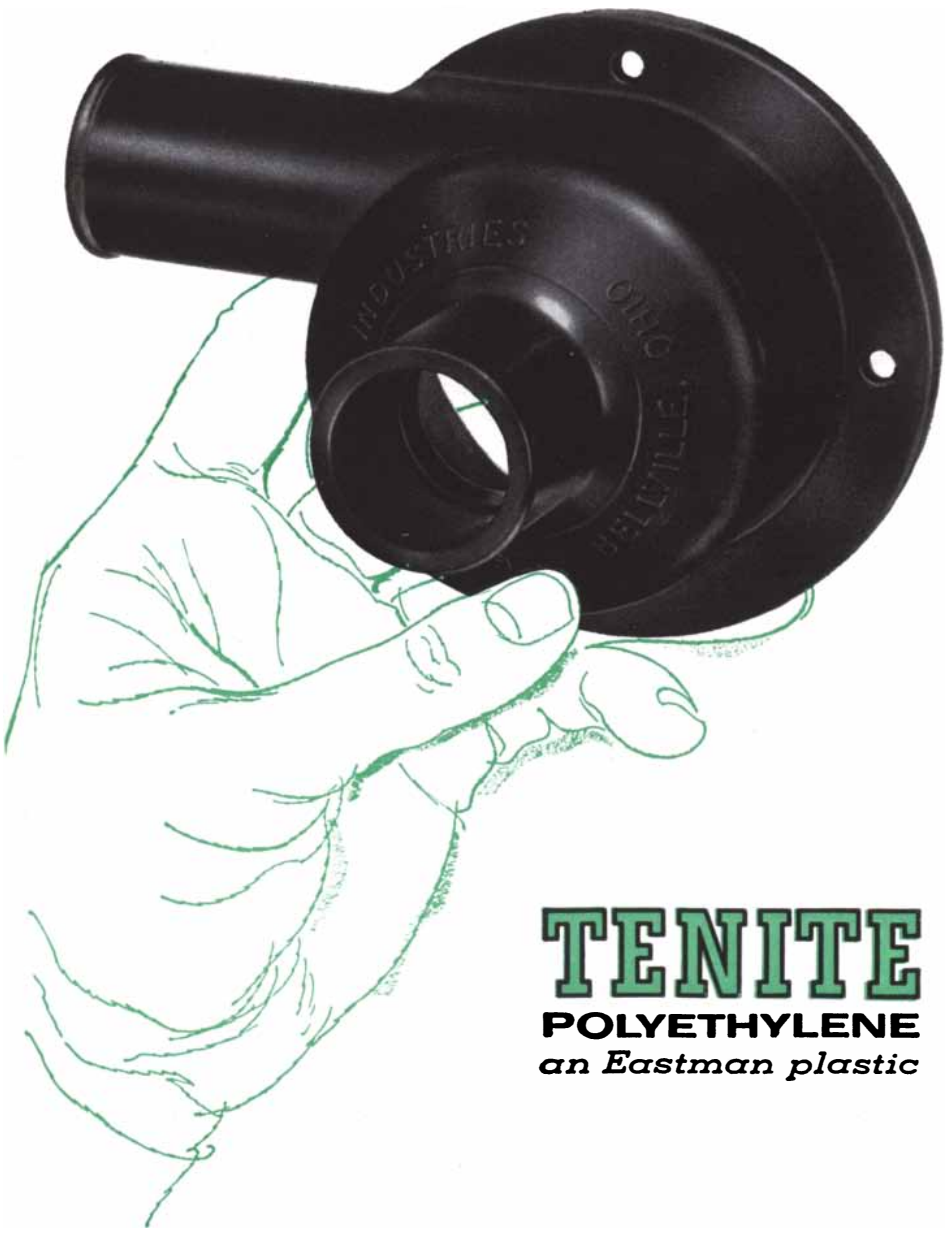

cuts material and fabrication costs... is strong, inert, corrosion-resisting

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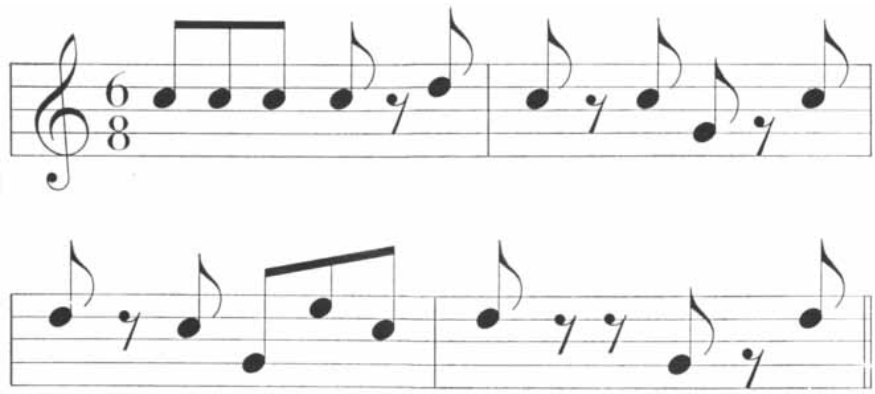

BANAL TUNE which appears above is one of the melodies contained in the tune-making network on page 78. This one is reminiscent of "Ride a Cock Horse to Banbury Cross."

must make a whole set of supplementary tables, taking account of the probability of occurrence of notes and pauses in each position of a measure. To make nursery tunes in 6/8 time we need at least six tables.

Just for fun, I have made a set of six such tables and composed a number of tunes from them. (The probabilities were rounded off to convenient fractions so that I could make the choices with a deck of playing cards. Of course other devices could be used—say a roulette wheel with a certain number of positions or even an electronic device hooked up to an electric organ which would play the notes as they turned up.) The melodies produced are sometimes a little startling, but on the whole quite tuneful. They are all "easy to catch on to."

From the six tables I have picked out some of the most common note transitions as a basis for composing tunes. I call it the "banal tune-maker," since it is hardly more inventive than a music box. The transitions have been reduced to a series of binary choices, so that at each step one of the two choices offered can be selected simply by flipping a coin. The diagram on page 78 shows the scheme in a network form. We shall follow the network in the direction of the arrows, and at each junction where we have a choice, we shall flip a coin and choose the black path if it falls heads, the colored path if it falls tails. We start with the note C (at the top of the diagram). For the next beat we have a choice of C or O (a rest). Suppose the coin turns up heads. C, then, is our second note, and the third note also is C, because it is the only choice offered along this pathway. For the fourth note we have a choice of C or G; say the coin falls heads, selecting C. The fifth beat automatically becomes a rest. For the sixth note, ending the measure, the choice is between D and C; suppose the coin falls heads and selects D. Let us say that this procedure, followed through four measures, yields the following result (H standing for heads, T for tails and a dash for points where there is only a single choice): – H – H – H/ – T H T H T/ – – H T T H/ – – T T H H/. Written out on a musical staff, the four measures are as shown at the top of this page. Our banal tune-maker has produced a tune which is rather reminiscent of "Ride a Cock Horse to Banbury Cross."

If we wanted to, we could construct a network no more complicated than this which would actually duplicate nursery tunes. However, the point of the exercise is not that the tables of probabilities can reproduce nursery tunes but that they indicate the essential rhythmic and harmonic elements that underlie all simple melodies.

Returning to the question of redundancy, how "banal" is our banal tune-maker? We can calculate, from the relative probabilities of the various possible sequences in a measure (30 in this case), that its redundancy is higher than 63 per cent. Its tunes are highly monotonous. Yet many of them are less monotonous than some actual nursery tunes—such as, for one horrible example, "A Tisket, A Tasket."

We can apply a statistical treatment not only to melody (a sequence of notes) but also to harmony (a group of notes sounded simultaneously). Indeed, an 18th-century composer, Jean-Philippe Rameau, made a statistical analysis of harmony similar in spirit to the approach we have used here, and Allen Irvine McHose has analyzed the compositions of Bach by modern techniques. There are high and low probabilities in the

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selection of notes for chords as well as for tunes.

Thus melody, rhythm and harmony can all be fitted into a statistical scheme. The clear implication is that we can build machines which will create music. A set of tables could be constructed which would compose Mozartian melodies or themes which would out-Shostakovich Shostakovich. We could get as close as desired to the style of any type of music without actually copying the melodies, and by altering the probabilities, we might evolve whole new styles.

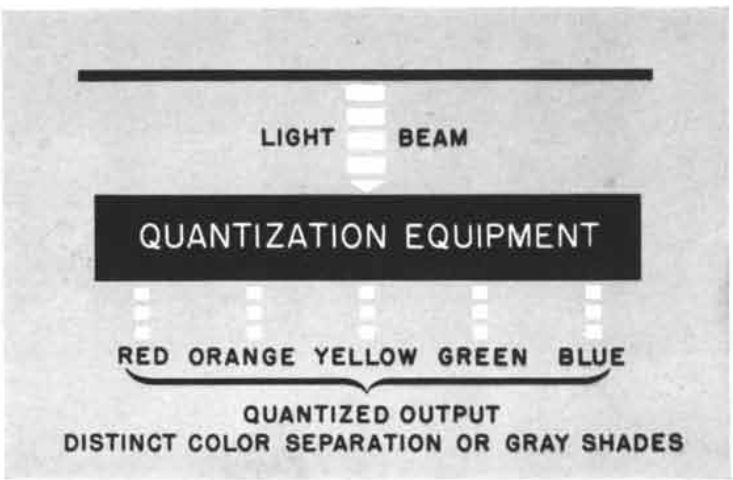
Thinking of our network scheme, it is fun to speculate that a composer's individual style may reflect networks of nerve pathways in his brain. These patterns need not necessarily be derived from the composer's study of music; perhaps they may be formed through some other sense channel. There is actually a piece of music which was composed after the pattern of the New York sky line. I like to think that our own banal tune-maker came by the hexagonal form of its network through its author's staring too long at some hexagonal tiles or inhaling too much benzene.

What has been accomplished by this excursion into music? First of all, we have been able to calculate an entropy, or average information per note, for certain kinds of elementary melody. This gives us an indication of the amount of meaning or information that can be expressed by such melodies. We have demonstrated that a certain amount of redundancy or repetition is necessary in order to have tuneful melodies. It is possible to give a quantitative measure of this redundancy. Viewed as a statistical process, the choice of a melody has certain periodic properties imposed on it by the rhythm. These are reflected in any mechanical or mathematical representation we might make for the process. It is possible to build machines which could make music having any degree of inherent entropy, redundancy and periodicity we might desire. Arrangements are underway to set up a random choice system on an electronic computer which will be capable of turning out thousands of melodies, less banal than those made by the coin-flipping network.

Information theory may well prove generally useful for studying the creative processes of the human mind. I don't think we have to worry that such analysis will make our art more stilted and mechanical. Rather, as we begin to understand more about the property of creativeness, our enjoyment of the arts should increase a thousandfold.

FORD INSTRUMENT QUANTIZES LIGHT

Colored lines or spots on a piece of paper can become a means of conveying information — Rorschach charts, impressionist paintings and survey maps are all visual message carriers. Ford Instrument engineers found it necessary to translate such color information into electrical or mechanical quantities, (quantization) with less distortion than is inherent in the usual photographic techniques. Such quantities can in turn be used as signals that actuate computers, make offset plates, and generally put to use the information implied by the difference between the colors or the distribution of the colors.



The quantization performed by Ford is not restricted to color alone. For example, a black and white photograph represents an aggregate of light and dark areas of varying shades, and this display must frequently be converted into continuous or discrete electrical quantities for various purposes and uses. Ford engineers recently developed equipment which can quantize and record the various degrees of color, or gray areas in photographic negatives, and to correlate this information into usable data. This equipment was developed for a classified project — the equipment is unavailable for general use — however the technical know-how gained by Ford — combined with Ford's superior production and engineering facilities — is available in the creation of light quantizing equipment for you.

Light quantizing is but one of the many facets of Ford Instrument design and development. For more information about Ford's products, services and facilities, write for an illustrated folder. Ford engineers will be happy to discuss your problems of control with you.

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Typical of Ford Instrument's 40 years of experience in precision control is its work in the field of nuclear power. The Company, for example, is building the control rod drive mechanism for the Seawolf, second atomic submarine. Reactor designs, sensing mechanisms, control equipment and systems, nuclear calculations, and other specialized equipment and abilities are offered by the Company to this expanding industry.

Tiny flowers were discovered on this 4,500-foot cliff near Umiamako Glacier on the west coast of Greenland

Small plants also sprouted from the bare surface of McGarry's Rock, which looks out over Kane Basin (see map on page 92)

FLOWERS IN THE ARCTIC

During the short summer of northern Greenland tiny blossoms emerge from crevices in bare rock. Some of these plants may survive from a time when hardwood forests covered the region

by Rutherford Platt

Halfway up the coast of Labrador a red spruce, tortured and fighting, stands as the last outpost of the tree line—the northernmost tree in this part of the world. Beyond it stretches a frozen wilderness where plant life soon seems to peter out altogether. Flying northward in an airplane, you see occasional green patches where crowberry grows in the tundra. If your course takes you over the south shore of Disko Island, just west of the middle part of Greenland, you may be lucky enough to see, nestling in a mountain sunbowl, a lush green meadow of flowers. But this solitary freak of nature—a natural botanical garden 150 miles north of the Arctic Circle—looks like the last bright burst of an expiring world. Northward, where the tundra ends, all signs of vegetation disappear, and from your plane you see only a sterile white world of ice and lifeless rock. Until recent years it was supposed that no flowering plants could grow in the polar region.

That plants may actually survive and flower in this frozen world seems inconceivable. And yet they are there for the finding. Tucked away among the rocks in that vast white expanse is an astonishing wealth of tiny wildflowers. Inured to the cold, dwelling in an environment where insects and diseases are unknown, they are the healthiest and most vigorous of all the world's flowers.

In 1947 and again in 1954 I had the happy opportunity to hunt these flowers as botanist with expeditions led by Commander Donald B. MacMillan. Both times we sailed in his schooner northward between Greenland and North America as far as Kane Basin, at the edge of the Arctic Ocean [*see map on page 92*].We explored more than 1,000 square miles of fiord, island and icy coast, and from the 1947 trip alone we brought back some 3,000 specimens of arctic flowers.

They were often as difficult to discover and pluck as the fabled edelweiss. With the schooner's bow thrust against a cliff, we would leap from the bowsprit to a narrow ledge to find a bluebell or a knotweed. We would land in a dinghy on a finger of the Greenland Ice Cap, scramble over the solid ice, and discover on the other side a sunpocket where fireweed and poppies grew in the shelter of huge rocks. Tiptoeing the ship in among offshore pinnacles of rock, we would climb a pinnacle and find in its crevices clumps of *Poa* grass or chickweed where birds made their nests.

It was on McGarry's Rock in Kane Basin, the northernmost point of our voyage, that we made the most surprising finds. This small island, looking like the back of a big whale just breaking water, faces the great polar ice pack. Its north slope was being ground under the pressure of millions of tons of ice. A strong, bitterly cold wind pours down from the Pole, and the winter tempera-

Expeditions were carried by the Bowdoin, *here moored to the rocks at Etah*

ture falls to 75 degrees below zero. Yet even there we found a few dauntless lichen living in the cracks. Judging by what we found on McGarry's Rock, I believe that seed plants would grow at the North Pole itself if there were any rock. On the south slope of the island we discovered pockets of saxifrage, flowering chickweed and grass with stems four inches long—giant plants for this part of the world.

How do these living things manage to survive? They are beaten ceaselessly by winds and swept by snows almost as dry as dust. They get only a scant eight weeks of sunshine and must wait out 44 weeks of polar night. The polar air and the rocks are as arid as the desert. There are no springs, no swamps or bogs, few level places. There is no soil, often not even a trace of sand, in which plants might gain a foothold.

Nature finds a way. Although the sunshine lasts only eight weeks, the plants can grow rapidly because they have it 24 hours a day. They live a largely hydroponic existence. Their water supply, of course, comes from the ice. From the melting glaciers in summer, water runs into crevices, puddles and cracks in the rock, where it dissolves minerals and makes a nourishing brew for the plant roots. For soil and a sheltering winter mulch the plants use dead leaves, which accumulate year by year with little decay. Most of them grow cactus-like leaves—leathery outside and filled with water inside. The leaves of some actually have coats of fur: among the hairy-coated ones are the mouse-eared chickweed, lousewort, grasses and the tiny polar buttercup (which is only one inch tall). All the plants are low-growing, usually less than ankle high. The showy blossoms of the fireweed and the arctic

Arctic primrose (Primula farinosa) *was found on Disko Island*

Mouse-eared chickweed (Cerastium alpinum) *is common in North*

Phyllodoce coerulea *is a member of the heath family*

Pedicularis lapponica *resembles a flower of the orchid family*

rose (*Dryas*) seem to bloom directly from the rock.

Hardiest of all the seed-bearing types are the mouse-eared chickweed (*Cerastium alpinum*), the red bulbil saxifrage (*Saxifraga cernua*) and the grass known as alpine foxtail (*Alopecurus alpinus*). These three musketeers belong to families notable for their hardiness throughout the world. Resistance is built into their genes. But to live on bitter McGarry's Rock they need more than hardiness. In the few short weeks of summer sun allowed, they cannot go through the full cycle of sprouting, tooling up for chlorophyll production, flowering, pollinating, fertilizing, ripening fruit and seed, and planting the seed. So these three species short-cut the long process of reproduction by seed.

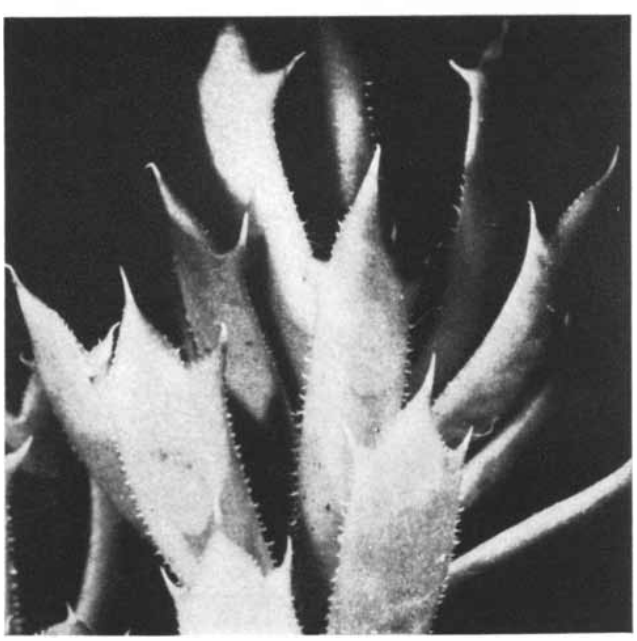
The red bulbil saxifrage bears no flowers at all. Clusters of tiny bulbs, which look like shiny red tops, form directly on its stem. These break off easily, roll a few inches away and can produce new plants vegetatively like a bulb. The grass has adopted the same device. In place of stamens, pistils and seeds it has scimitar-shaped bulbils, beautifully designed to dive to the earth when caught by the wind, like a kite without a tail, so that they fall close to the parent clump. Chickweeds everywhere are fast and ready with their flowering. In the U. S. they sometimes bloom all winter, opening their flowers at the least touch of sunlight. So it is not surprising that the chickweed flowers even on McGarry's Rock. Yet it apparently does not reach the seed-producing stage, and it, too, must reproduce vegetatively—by spreading its roots.

For all their hardiness and special adaptations, our three musketeers still could not survive on McGarry's Rock

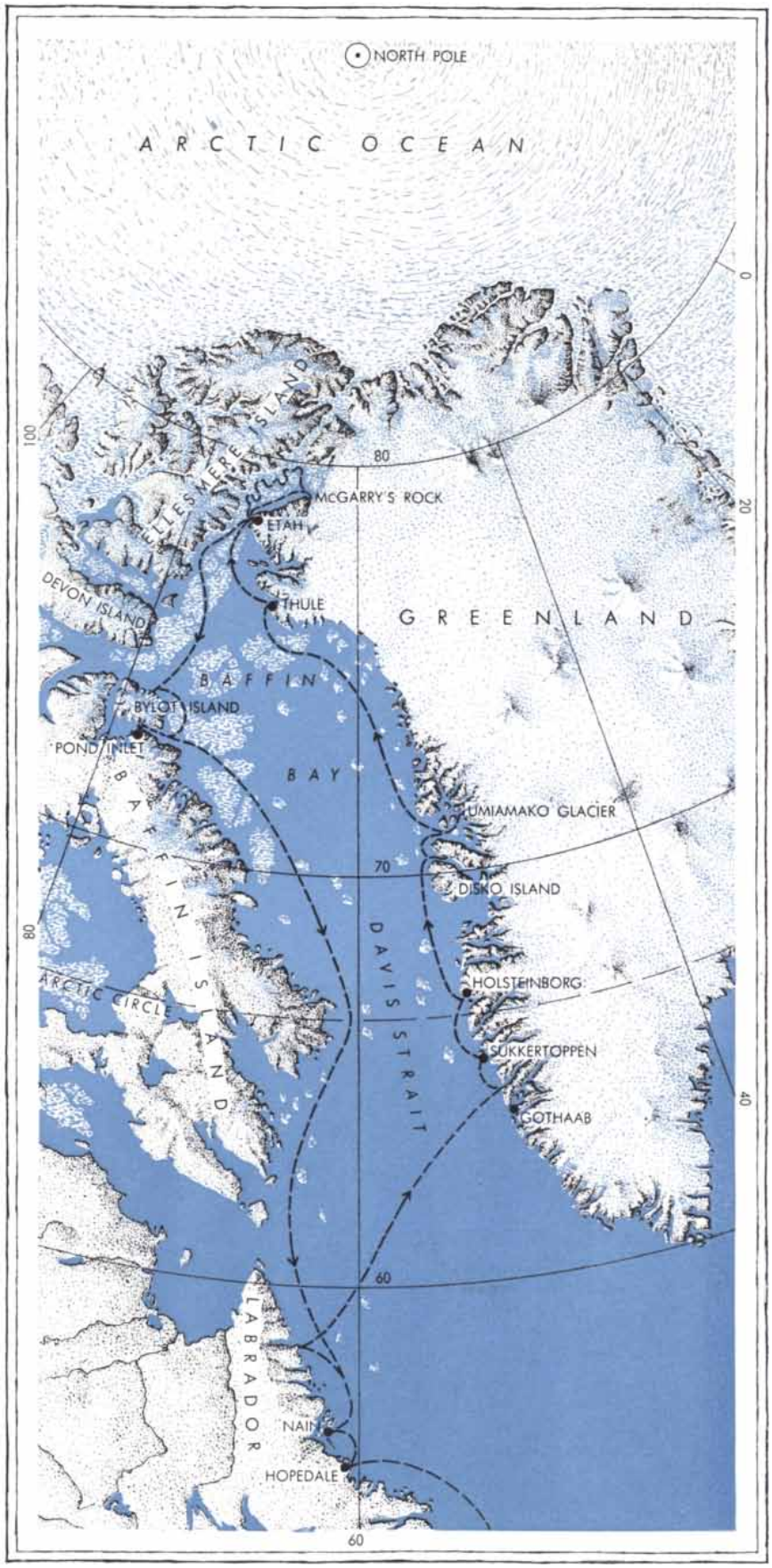
Eyebright **(Euphrasia arctica)** ***is a rare polar annual***

Golden saxifrage **(Chrysosplenium tetrandum)** ***has no petals***

Lychnis alpina ***is an abundant arctic flower***



Saxifrage leaves resemble cacti in their adaptation to dry climate



Map shows track of 1954 expedition. Kane Basin is between Greenland and Ellesmere Island

without the assistance of an equally hardy animal—the eider duck. The duck nests on the coldest rocks and ledges. It makes its nest of eider down plucked from its breast. Around its nest it cultivates a rim of living grass—a circular mound of alpine foxtail. It deposits fertilizer on the rock in a circle of precisely the right diameter for its nest; there a corresponding circle of grass takes root and flourishes in the cuddling shelter of the nest. We found scores of these nests, each with a perfect circle of fertilizer and grass around the down, on McGarry's Rock. So far as I know this is the only example in all the world of birds practicing agriculture. The mats of living grass were thick with the accumulation of time: the plants and birds must have lived together in delightful symbiosis for many years, perhaps even for centuries.

The three musketeers on McGarry's Rock are valiant exhibits of how plant life can adapt itself to face incredibly hostile conditions, and live smartly by taking advantage of every little local opportunity. But the richest polar oasis we discovered was at Refuge Harbor, on the Greenland coast east of McGarry's. It is a gem of a circular bay, almost completely surrounded by granite mountains topped by domes of the ice cap. We climbed up a sun-catching valley, through which a beautiful brook coursed down from the melting ice, and at 900 feet above sea level we beheld a breathtaking view of the ice-locked mountains of Ellesmere Island across Kane Basin, and of thousands of square miles of the silent, mighty ice pack stretching in unbroken majesty northward to the Pole.

Here near the northern tip of Greenland we found two major botanical surprises. The moment we landed on the rocks at the water's edge we encountered species of plants which so far as I know had never before been seen growing anywhere except high on mountains. At this far northern latitude (close to 80 degrees North) these "alpine" species—the opposite-leaf saxifrage (*Saxifraga oppositifolia*) and a poppy (*Papaver radicatum*)—had come down to sea level and were growing literally on the beach at the water's edge. The discovery was all the more remarkable because even in the Arctic, not quite so far north, mountain species generally seek high places—perhaps to get a little more light.

The other surprise was a vigorous colony of a strange species of saxifrage (*Saxifraga flagellaris*) that was unlisted

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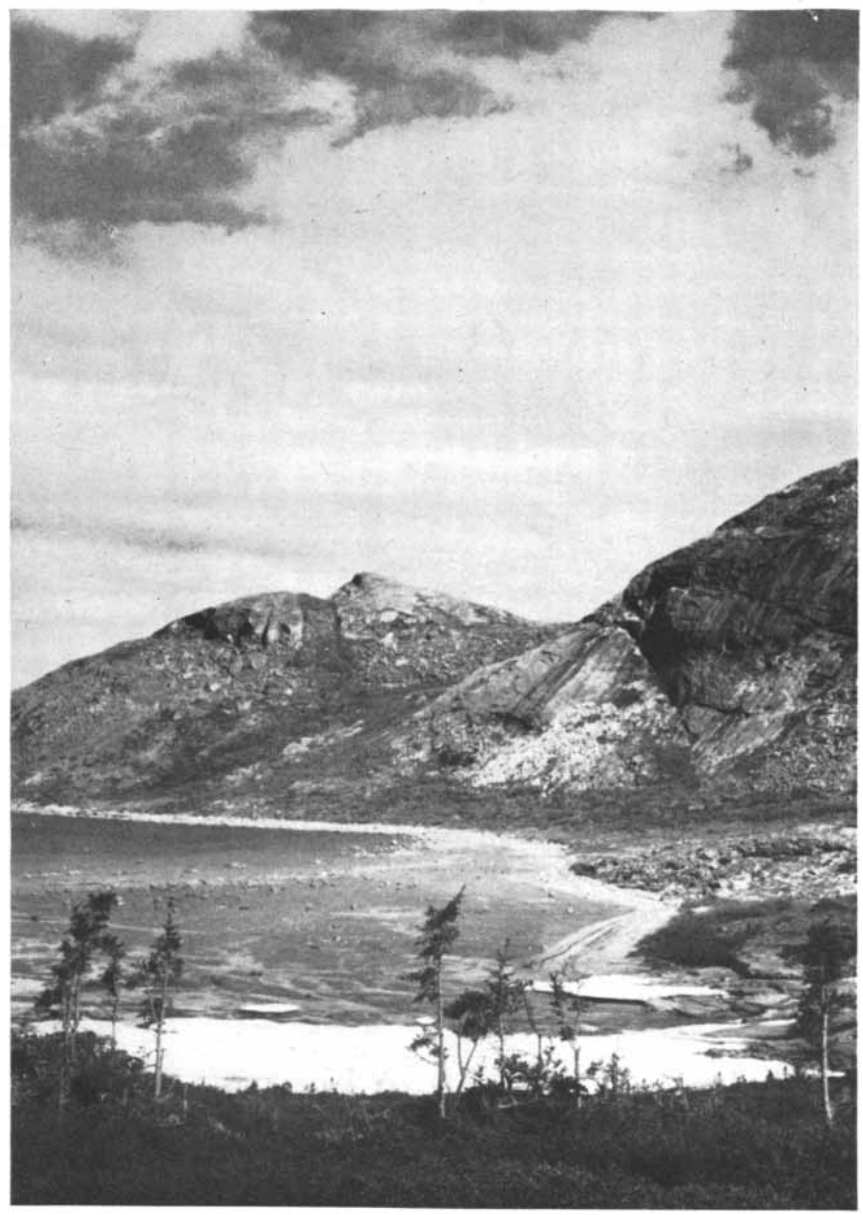
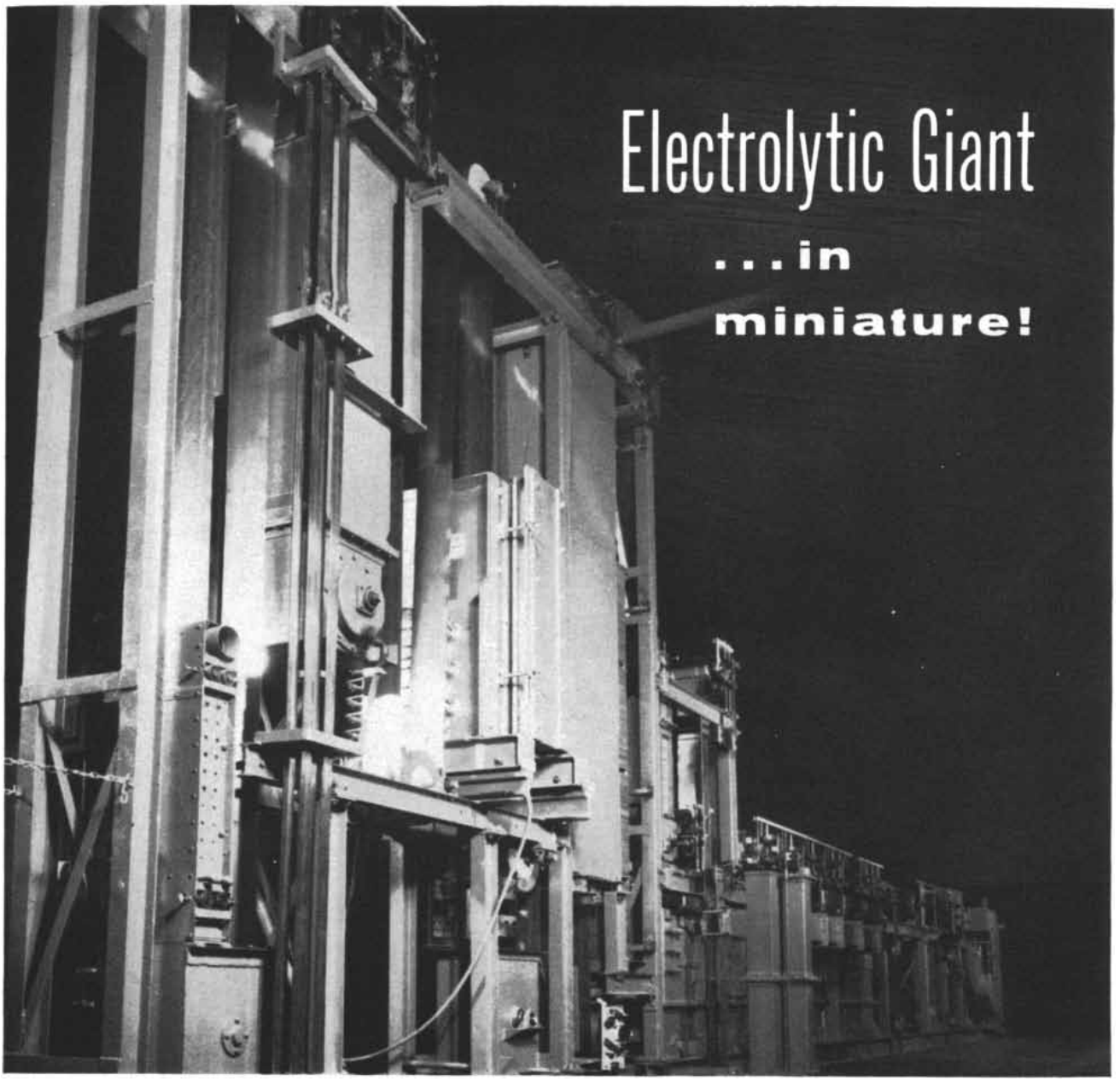
in the standard manuals of northern flowers. This peculiar plant sprouts from the base of the main stem six or eight red stems which curve up and out like streams of water spouting from a fountain. I call it the daddy-longlegs saxifrage. Each red stem carries at its tip a small bulbil, about a 16th of an inch in diameter, which it lifts up and over a stone and deposits on the other side. The quintessence of the surprise came a year later when the famous English mountaineer, Francis Smythe, in his book *The Valley of Flowers* reported finding the very same species of saxifrage at the snow line high in the Himalaya Mountains!

How account for the existence of precisely the same peculiar plant at two points thousands of miles apart, separated by oceans and continents? Unless you believe in a miracle of simultaneous creation of species in different places, you must suppose that the plant traveled around the world. In northern Greenland and on the highest mountains in the world in India it now finds the unusual conditions that favor its survival—clear, cold air, the brightest sunlight, a niche providing the nourishment of raw elements of rock. The real wonder lies in what this tells us about the history of the earth—the rise and fall of mountains, the spread and retreat of large-scale glaciations, the appearance and disappearance of land bridges between continents.

A century ago the eminent botanist Asa Gray pointed out the astonishing parallels between plant genera and species in northeast Asia and in the



Last trees seen by the 1954 expedition were in Labrador, 1,500 miles south of Kane Basin



This isn't the gigantic mill that it appears to be. Instead, it's a junior edition of a full-sized electrolytic tinning line. It measures a mere 100-feet long as compared to the 340-foot length of its big brothers in actual production.

Despite its comparatively small size, the job assigned to this miniature mill is a big one. Located in the new United States Steel Applied Research Laboratories, Monroeville, Pa., this pilot line transforms roll upon roll of 6-inch steel strip into shining tinplate at the rate of 800 feet per minute.

The tinplate produced on this pilot line is used for research studies in United States Steel's continuing research campaign to improve the protective qualities of tinplate and to make even better cans for foods and the variety of products packaged in cans. These objectives are so important that more than ten-thousand tests are made on tinplate each week in the Applied Research Laboratory.

By working in close cooperation with the tin container and food packing industries, United States Steel Research Engineers have been able to contribute substantially to the production of finer, more protective tinplate products, which, in turn add to the ever-expanding variety of canned goods to be found in the marketplaces of the world. It illustrates how United States Steel is constantly working to give America finer and more efficient products made of steel. United States Steel Corporation, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

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In the Arctic eider ducks fertilize circles of grass around their nests

northeastern U. S. In our own day A. C. Seward and others have advanced the theory that during the Upper Cretaceous Age an Arctic forest circled the earth around the Pole, and that when the Ice Age sheets spread southward later, arctic plants moved down into the eastern U. S. and Europe. So plants evolved in the Himalayas may well have traveled around the earth by way of the Arctic and come to North America over a land bridge at Bering Strait—or *vice versa*.

On the western coast of Greenland about 300 miles north of the Arctic Circle, the geologist of our expedition, William E. Powers, spotted an exposure of Upper Cretaceous sandstone. We attacked the shale with crowbars and mallets, and we unearthed many fossil remains of the arctic hardwood forest of 75 million years ago. My notes, made on the spot, say: "Here were the outlines of leaves, twigs, wood, . . . what seemed to be the tip and lobes of sassafras. . . . I thought I found the perfect imprint of sycamore—another, part of a large fig leaf. Most common were the imprints of elm seeds." The elm seeds were easy to identify, with their circular wings like hat rims. I shall always believe that our crowbar dislodged a piece of shale recording where, in a climate like that of present-day New England, rain water

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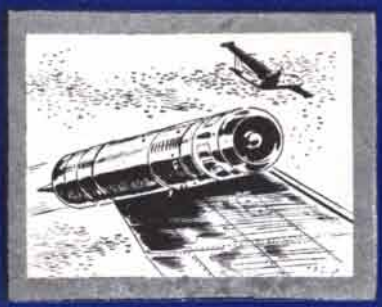

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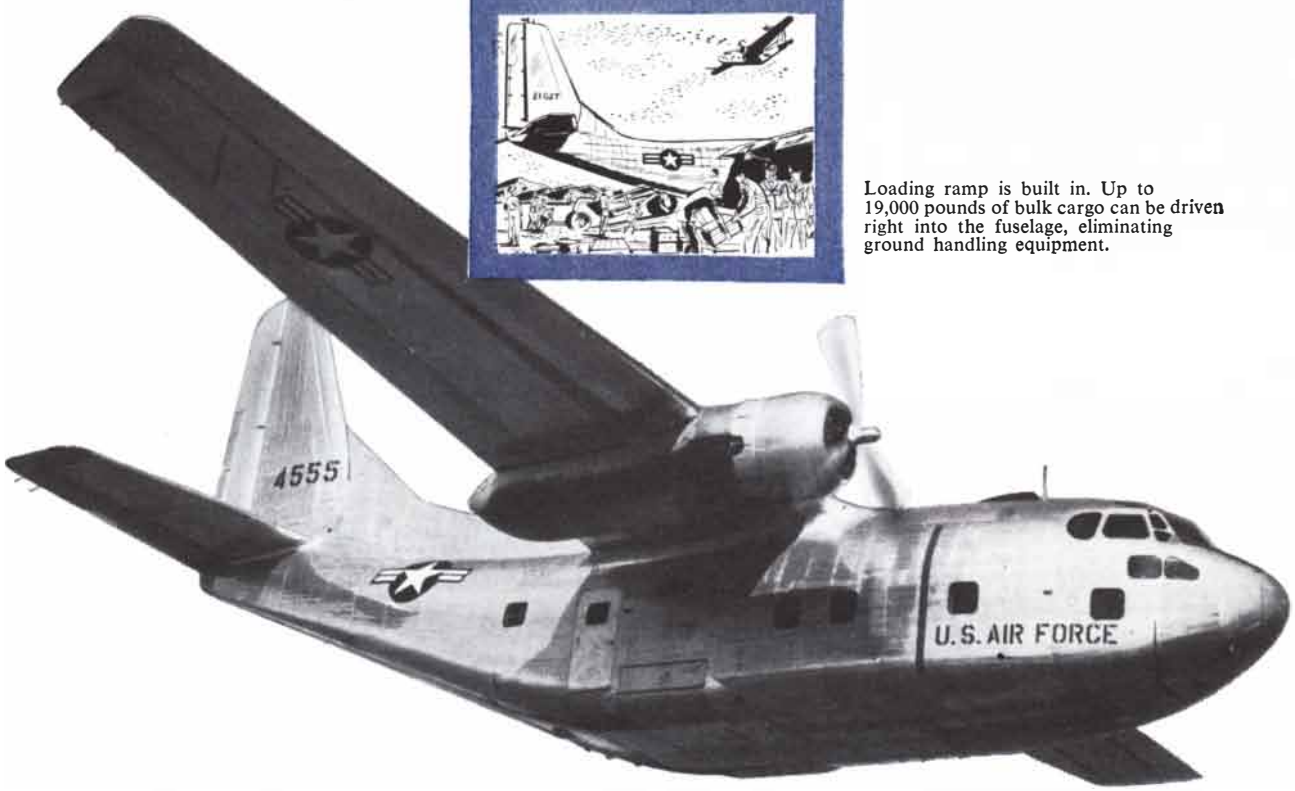
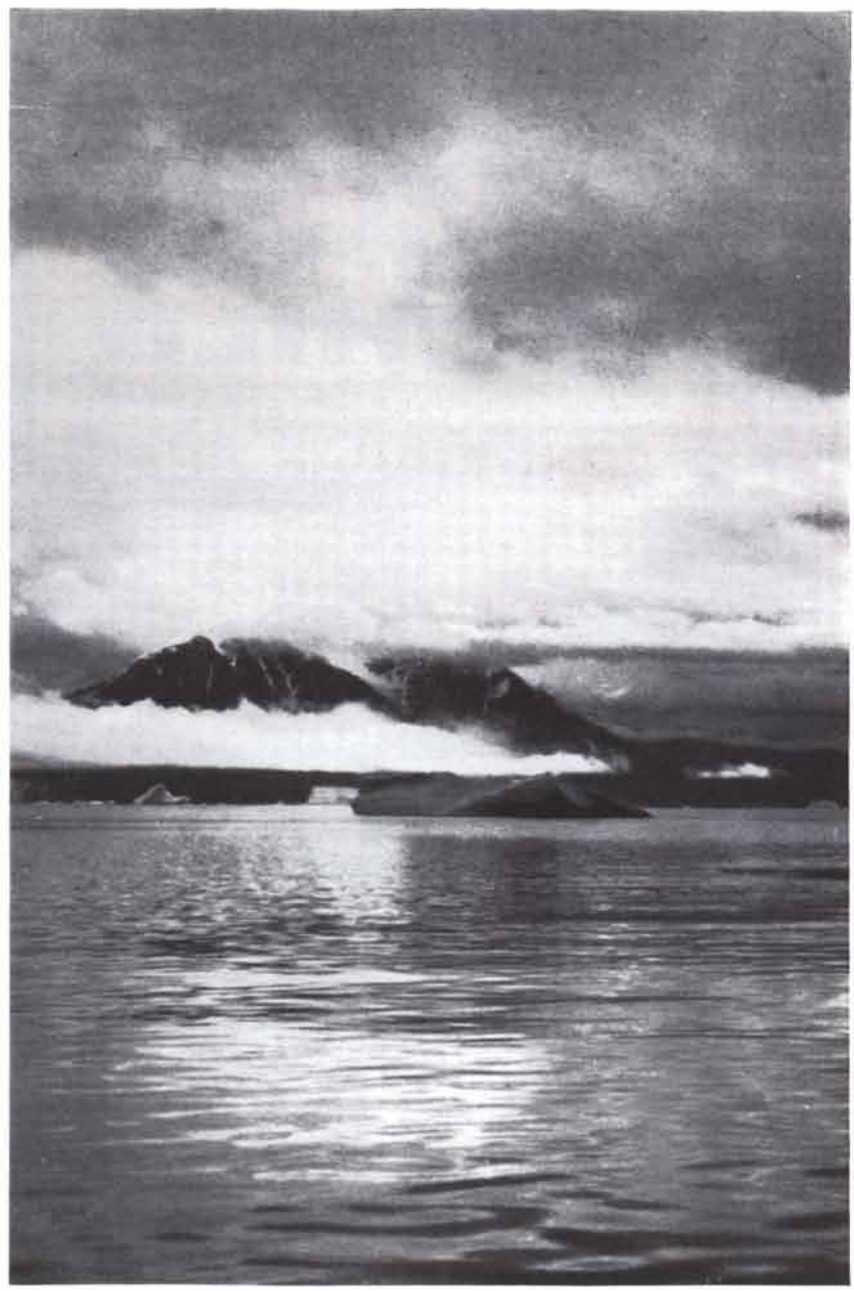


had washed elm seeds together those millions of years ago as rain washes them together in the gutters of our elm-lined streets today.

We piled up our treasure of fossils in the ravine where we had dug them out and returned to the schooner for a cup of coffee and more help. But within the hour a strong wind sprang up, a snow squall struck the ship and moving icebergs literally pushed the schooner out of the cove. We could not regain the shore. On our second expedition, seven years later, some of us went back to pick up the pile of fossils, but our ravine was beyond reach: prodigious icebergs made a landing on the shore impossible.

I had carried away one small stone in my coat pocket in 1947. A paleobotanist identified its imprint as a seed pod of the redbud-leaf tree (*Cercidiphyllum*). This tree today is a large native tree of Japan. It may be that the redbud-leaf tree and the odd "daddy-longlegs" saxifrage we found in northern Greenland were travelers from the Himalayas in the circumpolar forest 75 million years ago. Somehow they got stalled in Greenland—by a great change of climate or by the rise of oceans. The little saxifrage was able to continue to live in north Greenland, as its brothers did on the Himalayan heights, but the tree could not take Greenland and perished.



Rocky coast north of Disko Island bore fossils of a hardwood forest

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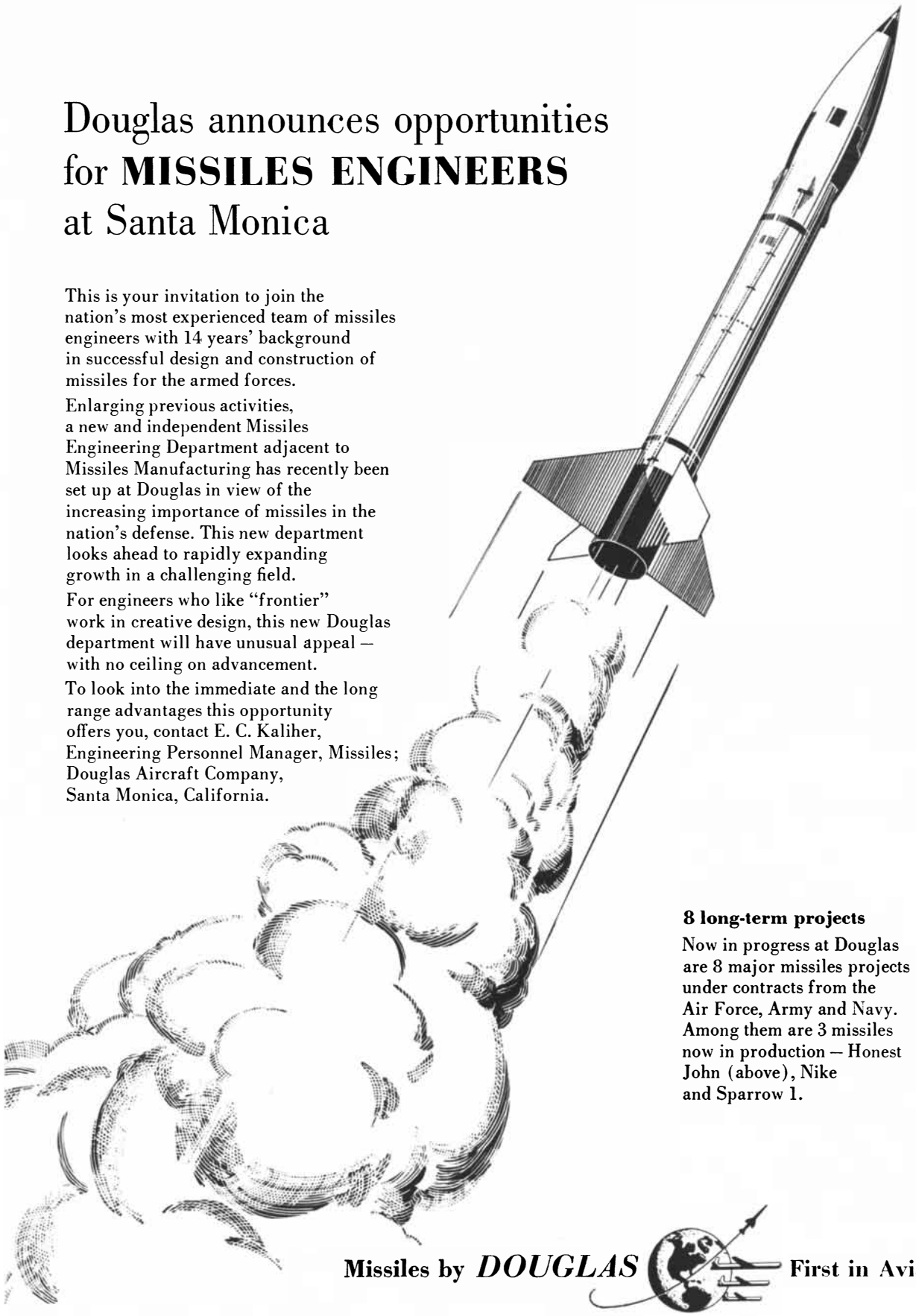
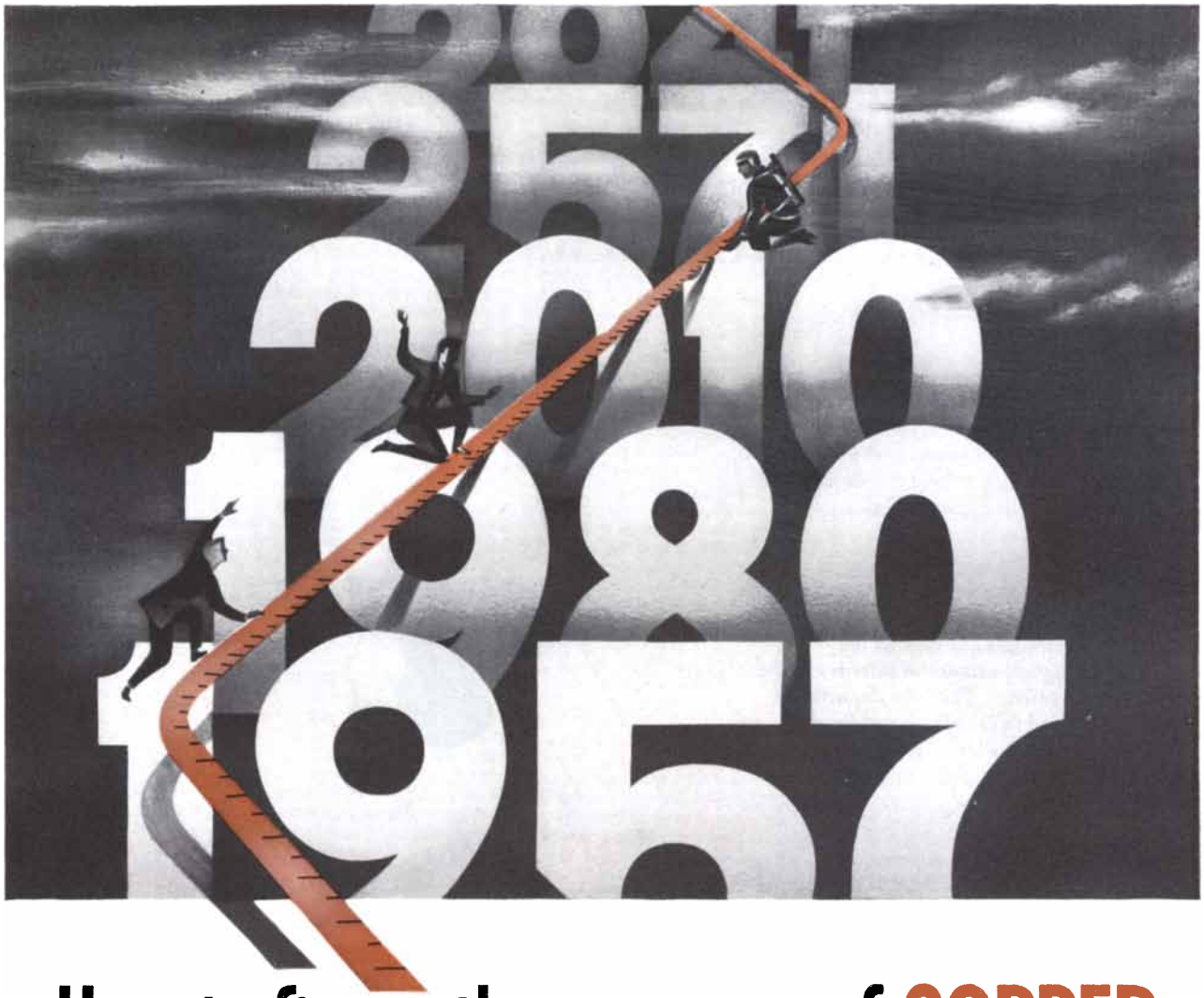


8 long-term projects

Now in progress at Douglas are 8 major missiles projects under contracts from the Air Force, Army and Navy. Among them are 3 missiles now in production — Honest John (above), Nike and Sparrow 1.

Missiles by *DOUGLAS* **First in Aviation**



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Barriers in the Brain

The walls of the blood vessels in the brain regulate the passage of substances which affect its metabolism. Brain disorders tend to make this barrier more permeable. Two red dyes curiously make it less so

by Robert B. Aird

In 1935 Stanley Cobb, the distinguished professor of neuropathology at the Harvard Medical School and psychiatrist-in-chief of the Massachusetts General Hospital, arrived at the annual meeting of the American Neurological Association with a basket of pink rabbits under his arm. Dr. Cobb was so absorbed by the story his rabbits had to tell that he had forgotten, like the proverbial absent-minded professor, to bring his dinner jacket for the society's banquet.

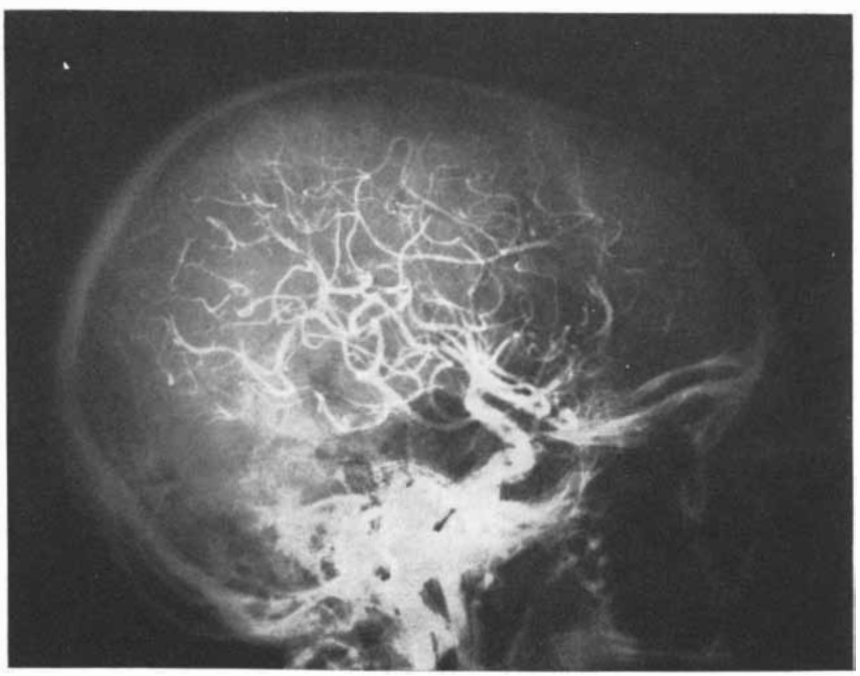
The rabbits were pink because they had been injected with a dye called "brilliant vital red." Cobb's news was that he and his co-workers had discovered that this dye had a protective effect against convulsions stemming from the brain. The dye itself was harmless. When injected into rabbits, it increased their resistance to convulsion-producing drugs. Cobb had also tried the dye on a small group of children subject to epileptic convulsions and found that it gave them protection.

This report by my former professor at Harvard was intensely interesting to me, because I was investigating epilepsy and because my colleague at the University of California, Herbert Evans, had done some work with the same dye. It appeared that the dye, when injected into an animal's bloodstream, stained the cells lining the inner walls of the blood vessels but did not normally reach nerve tissues. How could a mere dye which did not even get into the central nervous system have a counteracting effect against epilepsy? This puzzle started a train of investigation which 20 years later is even more absorbing than when it began.

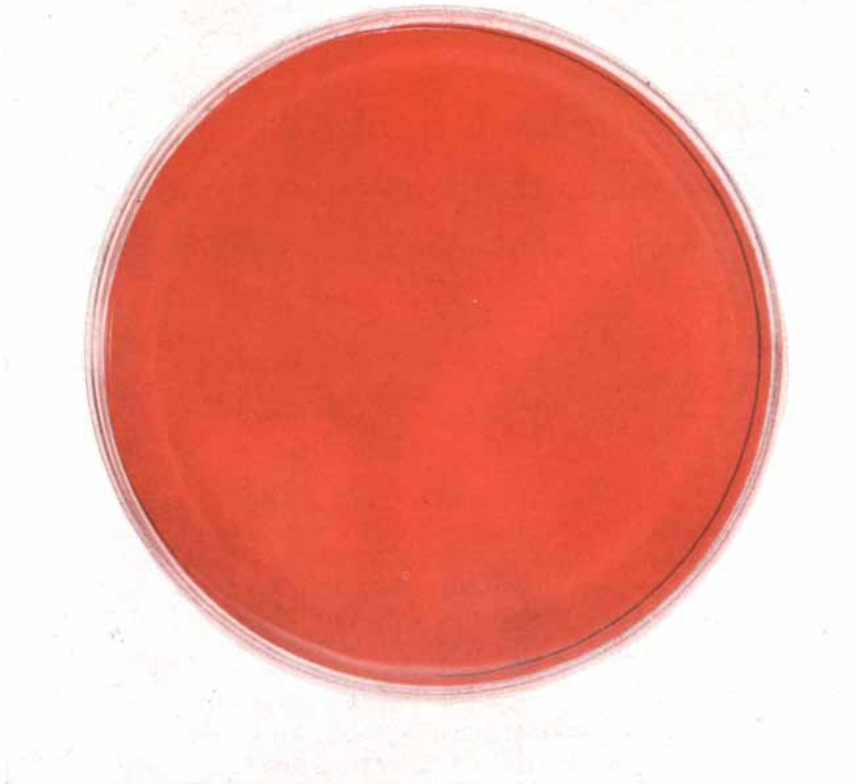
We set out to explore the question in our laboratory at the University of California Medical School. After confirming Cobb's observations of the dye's effects, we began a systematic study of its physiological action. Various experiments demonstrated conclusively that the dye did not penetrate into the nerve tissue of the central nervous system. Chemical studies also made clear that it could not be acting as a neutralizer of the convulsive drugs. But the dye's peculiar tendency to stain only the lining of blood vessels suggested a possible mode of action. Perhaps it made blood vessels relatively impermeable and thereby blocked convulsive agents from reaching the nervous system.

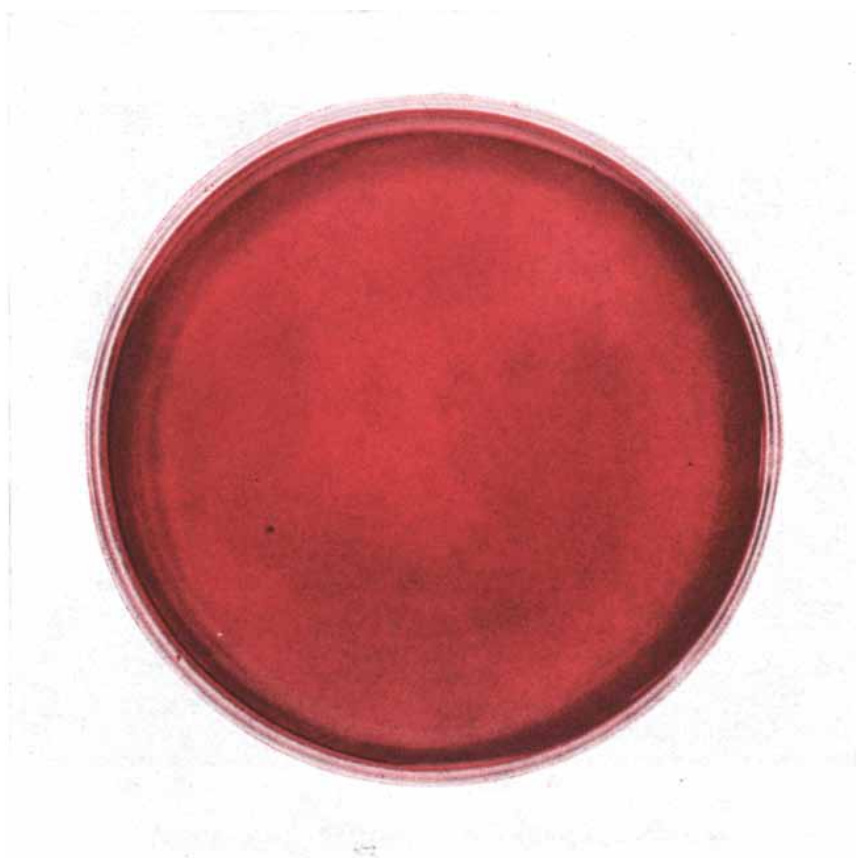
To test this possibility we injected cocaine, a known convulsive agent, into the bloodstream of dogs. The drug usually passes freely into the cerebrospinal fluid, but when the dogs received injections of brilliant vital red beforehand, the amount of cocaine entering their cerebrospinal fluid was sharply reduced.

The experiment thus confirmed that the dye could cause the lining of the blood vessels to act as a barrier against the passage of cocaine—and presumably other convulsive agents—into the central nervous system. But it also meant much more than that. It appeared to locate definitely (in the blood vessel lining) a "blood-brain barrier" which had interested physiologists for a long time. The bar-



LARGE BLOOD VESSELS of the brain are traced by this X-ray photograph of the head. The vessels were made visible by injecting a substance relatively opaque to X-rays into the blood.





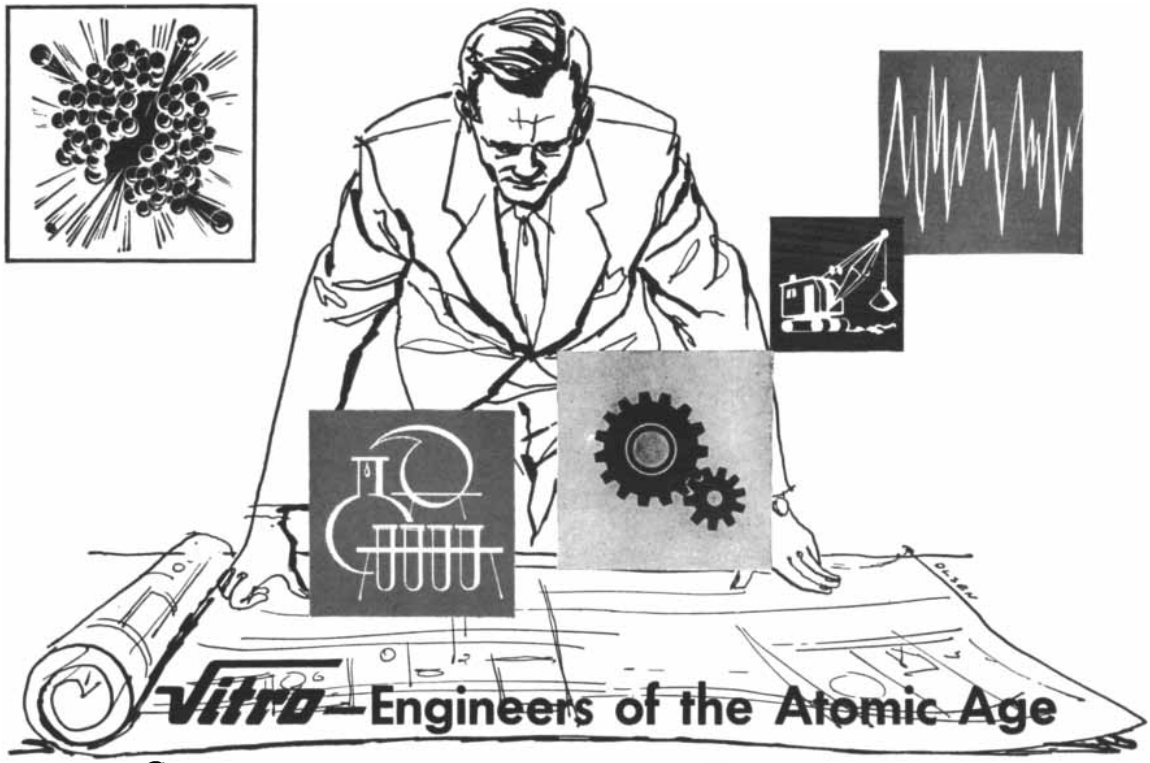
RED DYES which make the blood-brain barrier less permeable were poured into these dishes. The photograph above shows "brilliant vital red"; the photograph below, "trypan red."

rier has an important function and seems to be involved in all manner of diseases of the central nervous system. With the discovery of a means of altering the permeability of the barrier, we could proceed to investigate it experimentally.

The brain has a metabolism which differs slightly but distinctly from that of the rest of the body. It differs in its chemical balance and in its requirement of substances. Consequently the brain must have a barrier mechanism which admits desirable substances in proper concentrations and screens out those that would be harmful to the nervous system. Various studies have indicated that practically all disorders of the central nervous system—whether caused by injury, infection, tumors, toxic substances or whatever—tend to break down this barrier. Now our own investigations suggested that impairment of the functioning of the barrier—any abnormal change in its permeability—might itself be a cause of brain disturbances, leading to convulsions. Such an impairment might alter the brain's chemical condition and thus make it hyperreactive to stimulation and more susceptible to the type of mass discharge responsible for convulsions.

With this thought in mind we began a systematic study of the effects of various agents and diseases on the permeability of the barrier. As the control dye we used either brilliant vital red or trypan red, which is retained by the body longer than brilliant vital red, and as the tracer we usually employed cocaine. By doing identical experiments with and without the dye, we could check whether permeability of the barrier was in fact related to the observable effects of the agent or disease under study. We had developed a spectrographic technique which enabled us to measure with considerable accuracy the amount of cocaine that penetrated the barrier into the brain and cerebrospinal fluid. In collaboration with Louis Strait and other colleagues, we carried out a number of experiments with animals and studies of human patients suffering degenerative diseases of the central nervous system.

We first tested certain toxic substances. One, for example, was triphenyl phosphite. This agent was known to produce epileptic convulsions. We found that it actually had two effects. The phenol fraction caused convulsions immediately; the phosphoric acid fraction was absorbed by the gray matter of the spinal cord and brain and caused degenerative changes in the nervous system—



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changes similar to those in the condition known as Jamaica ginger paralysis.

Prior treatment with the dye succeeded in preventing these toxic effects. However, it should be added that the dye treatment cannot be expected to be successful against all toxins, because some penetrate the barrier more easily than others.

Next we considered the effects of injury to the brain. A concussion of the brain produces shock waves which very likely have a disruptive effect at the junctions between blood vessels and nerve tissue, altering the permeability of the blood-brain barrier. We subjected cats to a brain concussion, not severe enough to cause any obvious brain damage, and later injected cocaine into the bloodstream. A substantial amount of the cocaine penetrated to the animals' cerebral cortex, whereas much less cocaine reached the brain in another group of cats which had not received a concussion. The results indicated that the cerebral concussion had increased the permeability of the blood-brain barrier. This conclusion was confirmed by the further finding that preliminary injections of trypan red blocked the passage of cocaine into the brain of concussed cats; that is, the dye counteracted the effect of concussion upon the blood-brain barrier.

We examined the cats' brains by means of electroencephalography; three days after the concussion 80 per cent of the concussed cats showed abnormal brain waves. In contrast, the cats that had received protective injections of trypan red showed little or no brain-wave abnormality.

It is hoped that trypan red dye or some other safe agent can be used to test the relationship of permeability and brain-wave effects to the symptoms of human patients who have suffered brain concussion.

After the concussion experiments we looked into the effects of electric shock. Although this treatment has been used by psychiatrists for many years, the reason for its beneficial action is still unknown. We thought it likely that electric shock would affect the blood-brain barrier, on the theory that much of the electric current probably passes along the blood vessels. Our experiments consisted in giving animals electric-shock "treatments" like those ordinarily administered to human patients, and then injecting the tracer cocaine. As we had suspected, electric shock did appreciably increase the permeability of the blood-brain barrier. The effect persisted for

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Jack

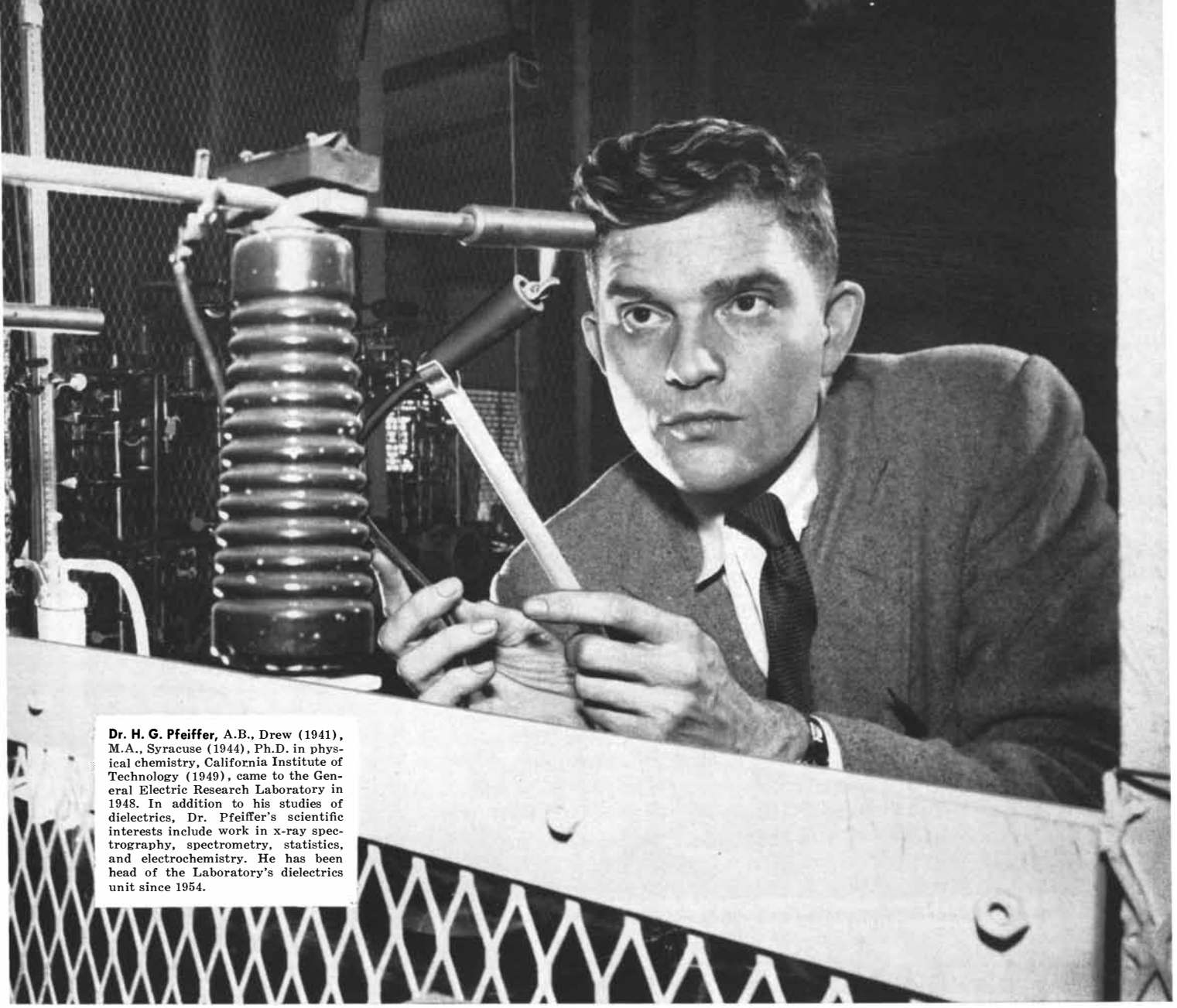
days. The electric-shock treatment also produced the same disruption of brain-wave rhythms that concussion had. And its effects were similarly counteracted by trypan red.

It would be interesting to investigate whether the dye can block the psychological effects of electric-shock therapy. The practical difficulties of such an investigation are obvious, but suitable methods are being sought to test the possible relationships between the permeability and brain-wave changes and the psychological changes. If it turns out that a change of permeability is the beneficial factor, more desirable methods than electric shock might be developed to bring about this change.

Our studies have shown clearly that the blood-brain barrier plays an important role in disorders of the central nervous system. But before any medical use can be made of this knowledge, we must learn a great deal more about the barrier. We shall have to develop safe and reliable ways to test and alter the permeability of the barrier in human patients. Studies must be made of just how the barrier works, and how its functioning is affected by biochemical factors in the central nervous system and by various agents and treatments. We must also find out what chemical and physical properties permit substances to pass through the barrier under normal circumstances.

With these points in mind, a long-range program of study has been started with the aid of grants from the U. S. Public Health Service. So far we have worked mainly on investigation of the nature of the barrier itself, using various tracers to test its permeability in terms of the electric charge, molecular size and solubility of substances. This study has confirmed our opinion that the barrier functions in a complex manner. It appears that substances may penetrate the barrier by at least two routes: fat-soluble substances through the membranes of the endothelial cells in the blood vessel walls, and water-soluble substances by way of "pores" between the cells.

Once the basic functioning of the barrier has been worked out, it may be possible to learn how this functioning breaks down during disturbed states of the central nervous system and what corrective measures could be applied. In the meantime, the present program of experiments should tell us a great deal about the relationship between permeability of the barrier and such effects as convulsions and certain abnormal brain waves.



Dr. H. G. Pfeiffer, A.B., Drew (1941), M.A., Syracuse (1944), Ph.D. in physical chemistry, California Institute of Technology (1949), came to the General Electric Research Laboratory in 1948. In addition to his studies of dielectrics, Dr. Pfeiffer's scientific interests include work in x-ray spectrography, spectrometry, statistics, and electrochemistry. He has been head of the Laboratory's dielectrics unit since 1954.

Dielectric research that can lead to improved insulators

Dr. H. G. Pfeiffer leads General Electric study group

Science has found perfect electrical *conductors* (several elements are "superconductors" at temperatures near absolute zero), but the perfect *insulator* has not been achieved — and may not exist. Although theoretical perfection may be unattainable, scientists are convinced that better understanding of "breakdown" and similar phenomena will lead to improved insulating materials for many practical applications. At the General Electric Research Laboratory a group led by Dr. H. G. Pfeiffer is finding significant new fundamental knowledge about the sources of electric strength. For example, their study of liquid insulators has shown why the *area* of electrodes has a substantial effect on transformer-oil breakdowns. Their work also has shown that the sparking potential of simple hydrocarbon gases can be predicted from molecular structure. Now Dr. Pfeiffer and his associates are applying insight gained from studying liquid and gaseous dielectrics to help solve the even more difficult problem of understanding what keeps electrons from moving through solids.

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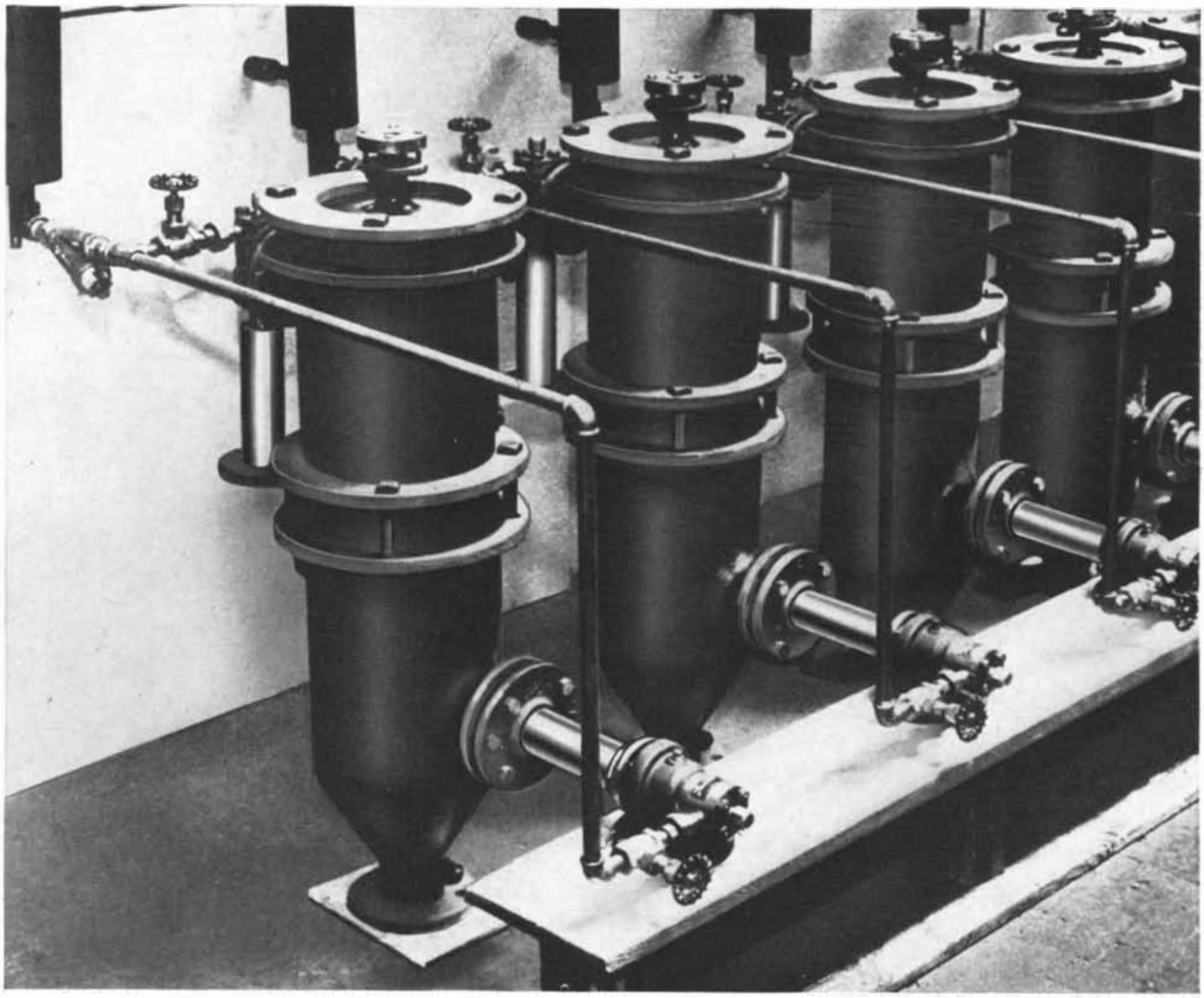

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HEAT, COLD AND CLOTHING

The physiological mechanisms which maintain the internal environment of man operate in a limited range of external environment. This range is extended by the use of clothes

by James B. Kelley

The human body is a heat engine with a built-in thermostat. It takes in fuel, "combusts" it and puts out useful work. To be sure, it is a kind of heat engine which engineers cannot yet, even in their most fanciful moments, dream of building: a machine that not only generates the energy for its work but also makes cells, blood and tissues, rebuilds worn-out parts and repairs and maintains itself. It operates in a highly complex way. But from the point of view of protecting it from external heat and cold we can think of it simply in physical terms as an engine of extraordinary sensitivity and adjustability.

It must keep its internal temperature fairly constant. The "normal" temperature of good health is commonly taken to be 98.6 degrees Fahrenheit, and a variation of a degree or two is likely to result in a call for a doctor. But body temperature can vary substantially even in healthy people. E. F. Du Bois of the Cornell University Medical College took the temperatures of his class of 276 medical students one morning: only 38 were in the "normal" range between 98.4 and 98.8 degrees; two thirds of the students had "subnormal" temperatures below 98.4. Exercise will raise the internal temperature appreciably. Healthy persons after strenuous exercise in laboratory tests commonly run a temperature of 102 degrees F. and sometimes go as high as 104. Usually their body temperature drops to the "normal" level shortly after they stop exercising.

Du Bois has shown that a change of 22 degrees F. in the outside air temperature causes less than two degrees of change in the rectal temperature. The skin, on the other hand, is highly responsive to outside temperature and is generally about 10 per cent cooler than the internal body temperature. It is also a sensitive detector of temperature changes: a small skin area in the center of the forehead detects differences as small as a hundredth of a degree centigrade.

During strenuous exercise the body dissipates the extra heat mainly by evaporating sweat. Although prizefighters use this "drying out" process to make weight limits, exercise is not an effectual way to lose weight, because the weight returns as soon as the person replenishes his body's water requirement. "Melting down" by exercise can have a debilitating effect on the system as a whole.

The body also can lose heat by convection (through contact or air movement) and by radiation to cooler surroundings. A cold shower or a swim in cold water on a warm day has an invigorating effect because, by speeding up heat loss, it dispels fatigue and headaches which accompany the too-slow transfer of heat from the body. But a cold shower at the start of a hot day may actually increase discomfort during the following hours because water vapor condenses on the cooled skin, producing the same effect as high humidity.

The way a person is clothed has a considerable effect on the routes by which his body loses heat. It has been shown by measurement that when a sleeping person is clothed in pajamas

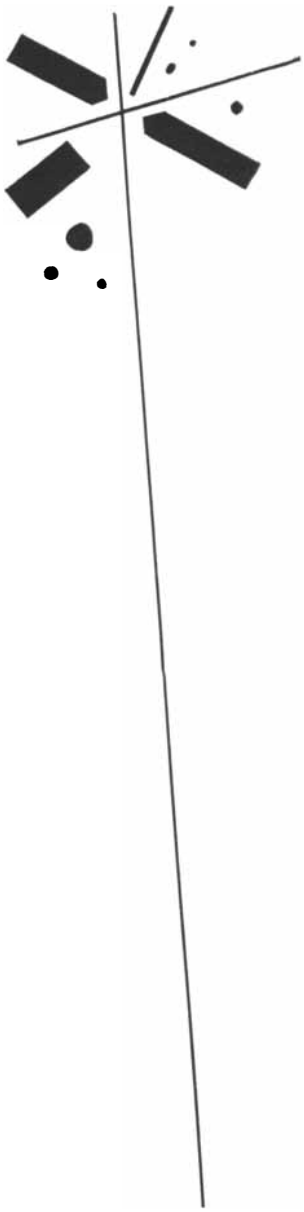
Desert peoples cover themselves with clothes for protection against the sun and dryness

The Eskimo may put his hands inside his parka to warm his face **(right)**

and covered by a sheet, 53 per cent of his heat loss is by radiation, 28 per cent by evaporation and 19 per cent by convection. If he is nude and uncovered, radiation accounts for two-thirds of his heat loss. A nude person engaging in exercise loses a smaller proportion of his heat by evaporation (22 per cent) than a clothed person while asleep.

Much of our present exact knowledge on the subject of heat loss comes from recent studies by the U. S. armed services of men's clothing requirements, particularly in cold climates. Naturally a great deal of attention has been given to the Eskimos, who seldom suffer frostbite and keep warm with only about one third of the weight of clothing GIs seem to need in Alaska. It used to be thought that Eskimos were physiologically different from white men. Under their normal living conditions they do have a considerably higher rate of basal metabolism—up to 33 per cent higher. But as Kaare Rodahl of the Arctic Aeromedical Laboratory has recently pointed out, Eskimos live on an exceptionally high protein diet—a little more than a pound of meat per day. When an Eskimo is fed the standard GI diet for Alaska, his basal metabolism drops to the normal Caucasian level within three days. On the other hand, persons who are put on the Eskimo diet quickly reach the Eskimo basal metabolism level. The studies to date have shown that at least two thirds of the metabolic difference can be traced directly to the Eskimo's high protein diet. The remaining third is thought to be psychological.

Of course familiarity with the climate and geography is a big advantage. The Eskimo has to understand how to live in severely cold weather if he is to live at all. Among other things, he has learned to choose clothing which gives the maxi-



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mum protection for minimum weight. With his lighter-weight clothing he can travel faster and farther and carry more food on a trip.

The Eskimo wears furs, even fur boots, and all his clothing fits him loosely. It is said that his dress is so capacious that he could turn his body around inside it. His parka extends far beyond his face, so that he is exposed to the wind only when he faces directly into it. He can remove his arms from the sleeves of his parka and bring his hands up inside the parka to rub his face to warm it. His hands are never exposed to the cold air.

Animal hides afford maximum protection from the wind. (The Russians often wear leather coats instead of fur.) The Eskimos' methods of curing hides and treating furs leave something to be desired from our point of view: they use animal urine for curing, so that in a warm, closed room their clothing has an extremely disagreeable odor.

A human being instinctively tries to reduce his body's surface area to the minimum when he is cold and expose it to the maximum when he is hot. You can make observations on this point right at home, as the writer of this article has on his five-year-old daughter. In common with all children she tends to kick the bed covers off while asleep, regardless of weather. When it is cold, although she wears a heavy sleeping garment she huddles into as small a ball as she can manage. In warm weather, when she wears only a thin nightgown or shorts, she stretches out in the form of an X. The huddled position reduces her body heat loss; the stretched-out position increases it by increasing the surface-to-volume ratio. The same postures are noticed in persons who have died of extreme cold or extreme heat. The former tend to be huddled, while the latter are stretched out, usually with their clothes torn from their bodies.

L. E. Shulman at Yale University investigated the physical results of adding layers of clothing. His "subjects" were blackened copper cylinders containing water at body temperature. He clothed these in underwear and one or more layers of Shelton cloth as outer garments. As successive layers were added, the heat loss from the cylinder was reduced

A child conserves heat by huddling (top) *and dissipates it by spreading out* (bottom)

SCIENCE AND ENGINEERING

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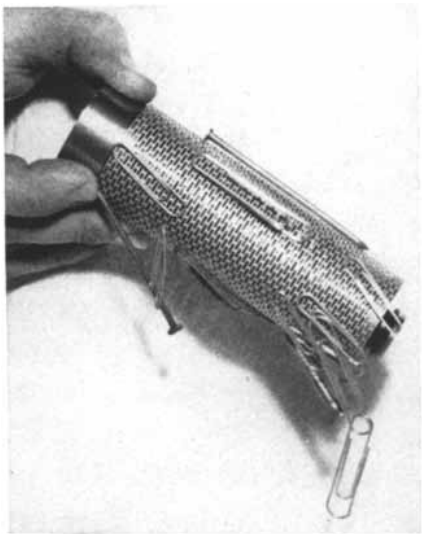

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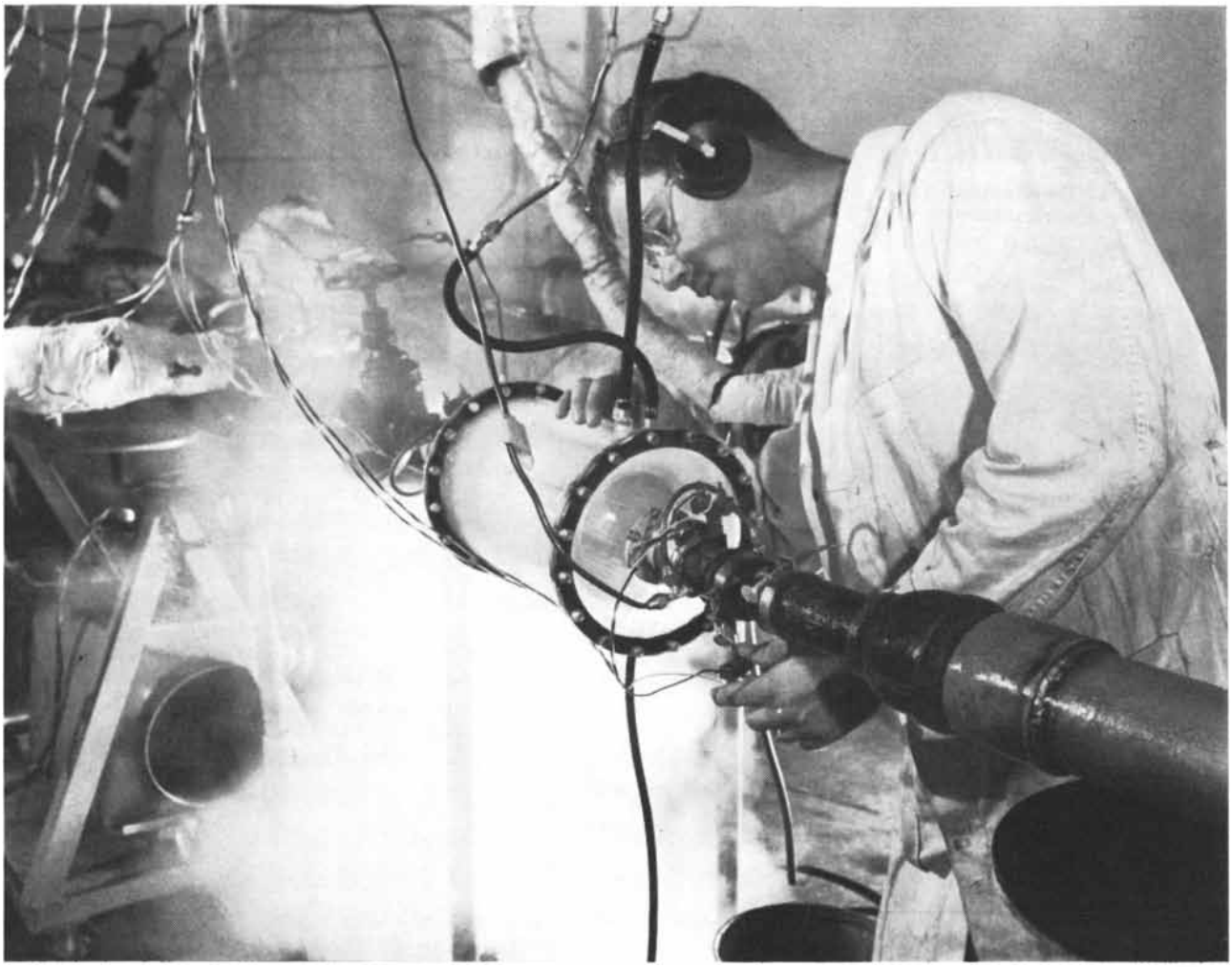
—up to a point. Each additional layer of course made the body bulkier and increased the surface-to-volume ratio. A turning point came when the fifth outer layer was added: the surface-to-volume ratio then was such that additional layers actually increased the heat loss. In principle this is the plight a small bug would be in if it tried to live at the North Pole: it would quickly freeze because it has too much surface area for its volume. Shulman's experiments proved that a law of diminishing returns operates in bundling up against the cold.

One of the principal causes of both danger and discomfort in cold weather is the wind. While animal hides offer excellent protection against the wind, it makes considerable difference whether the pile or fur is worn on the inside or the outside. If the fur is outside, the insulation value drops rapidly as the wind speed increases, but if it is inside, the protection given against the wind remains high. This helps to explain the popularity of fleece-lined garments in cold climates. It would seem, however, that the lambs from which the fleece is taken do not know much about physics, for if they did they would wear their fleece on the inside. Women might note that they could expect greater wind protection if they wore their mink coats inside out.

A. C. Burton and other workers have developed for the U. S. Army a measure of clothing needs which is useful even to people who do not live in severely cold climates. Burton's unit is the "clo," which is defined as the amount of clothing a seated man needs to be comfortable in 70-degree F. air with a relative humidity of 50 per cent and a slight air movement of 20 feet per minute. The difficulty with this definition is that comfort is a fairly subjective quantity, but then so to some extent is the entire subject of clothing. The man sitting in 70-degree air with one clo of clothing is losing 50 kilogram-calories of heat per square meter of body surface per hour. Wearing the same unit of

Workers may wear relatively light clothing in winter because of heat generated by exercise



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clothing, he loses heat at three times this rate while walking in 40-degree air, and at six times the rate while exercising at five degrees below zero. Sleeping in an unheated tent at 20 degrees below zero, he would need 11 clo units. If he had a stove which could keep the temperature inside the tent at 10 degrees F., he would need only eight clo units.

According to studies by John Talbot and the Climatic Laboratory of the Office of the Quartermaster General, it is impossible to make gloves of any reasonably manageable size which would offer sufficient insulation to the hands for a person who is at rest at 20 degrees below zero. At the same temperature, however, you may not need gloves at all if you exercise strenuously. The moral is: Keep moving.

At the hot end of the temperature spectrum the problem is essentially the same as at the cold end: namely, insulation. In the hot desert exposure of the skin to the intense sun and dry air can be fatal. In tropical regions the body must also be shielded against insects if one is not to be eaten alive. So in both extreme cold and extreme heat people have to wear clothes for survival, whereas in temperate climates the principal reasons may be merely modesty and custom.

The clothing used for insulation in a hot climate must be thick enough to keep off the sun's rays and yet porous enough to allow a suitable rate of evaporation. Much depends on the humidity of the air. In a dry desert region the inhabitants have to wear heavy clothing to prevent too rapid evaporation of the body's moisture. In the humid tropics the premium is on porosity. But to keep off insects one may have to compromise on less porous clothing at some sacrifice of comfort.

Wind, of course, is an important factor in high-temperature as well as low-temperature climates. The same helmet that keeps the head cool in a five-mile-per-hour breeze may be highly uncomfortable in still air. Nonetheless, you may have to wear the helmet for protection against the sun, even though it increases the temperature of the head.

In all climates appreciation of what is necessary to survive and be comfortable under the given conditions is the most important factor. The Eskimos are an outstanding example of a people who manage to get along under rigors of climate that would defeat most other human beings. They have been known to go off on two-week hunting expeditions with two quarts of whale oil as their only fuel. Each night the Eskimo builds a small igloo which is almost entirely sealed against the outside air. He burns a small amount of the whale oil in a stove inside the igloo for a short time in the evening, and this heat, together with his natural body warmth, keeps the igloo at a satisfactory temperature. The ventilation inside the igloo is very poor, but not so poor as to cause suffocation. The Eskimo has learned in the laboratory of human experience the most economical methods of dealing with his environment.

The Eskimo in the north, the Arab in the desert, the Negro or Indian in the tropics—all have been schooled in how to survive in their particular habitats. They are not greatly different physiologically from other peoples, but they have adapted their diet and their mode of life to their respective situations. Despite the severity of their climates, they probably keep more comfortable than those temperate-region inhabitants who winter and summer run away from home to balmier climes and often end up being quite uncomfortable.

In the wind a mink coat is better inside out

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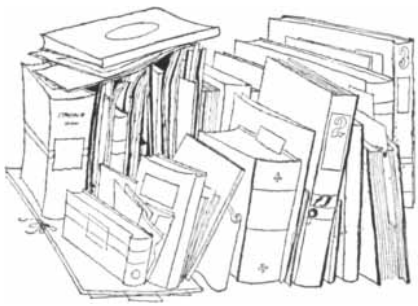

BOOKS

Hedgehogs and foxes: two schools of thought among 14 philosophers

by James R. Newman

THE AGE OF ANALYSIS, edited by Morton White. Houghton Mifflin Company ($3.00).

Professor White's book is part of a series whose purpose is to present and compare the ideas of the leading philosophers of the Western World. Each study in the series gives excerpts from the philosophers' writings with an interpretive commentary. Six volumes will span philosophy from medieval through present times. White's volume, the second to be published, covers the latest period—the modern philosophers.

I should make it clear at the outset that this is not a book for hammock reading at Old Point Comfort. Philosophy is not a cheap and easy enterprise, though there are popularizers who have cheapened it. Modern philosophy, concerned with logic, linguistics and science, can be as disagreeably difficult as any branch of thought yet devised. One of the merits of White's survey is that it does not attempt to pretty up philosophy. Most popular anthologies concentrate on the philosophers who make agreeable, sympathetic or charming reading. This study also tells "the other half"; it includes passages from the hard-bitten, technically minded analysts as well as from the bold and mellifluous system builders.

White suggests dividing the philosophers of the 20th century into two groups: hedgehogs and foxes. The image is drawn from a saying of the Greek poet Archilochus: "The fox knows many things, but the hedgehog knows one big thing." It serves to contrast two main tendencies in philosophy. The hedgehogs are the metaphysicists, who try to see the world "in terms of a central concept which is to organize all their attitudes and beliefs." They seek to explain all that the seen and unseen world has been, is and will be. Their philosophies may not always be a comfort, but they are always complete. There are no loose ends or exceptions: loneliness and starfish, molecules and bills of lading, greed and galaxies, time and art are all embraced in a single vision.

The foxes are known as the logical analysts. More modest and at the same time more arrogant than the metaphysicists, they deny that philosophy has to do with world views, that it has any business pronouncing grandly on religion, politics, morals, art or even science. They would like to know many little things—instead of one big thing—but they are content to know even one thing provided they can get to know it very well. One may vary the image of the foxes, and think of this second tendency as surgical. Using the sharpest possible instruments of logic and mathematics, these surgeons of philosophy are intent on excising small muddles which, if untended, may grow into big muddles. The object of attention is not the world or man or morals, but sequences of reasoning, sentences, even single words. Logical analysts are philosophers interested in the causes and cures of philosophy. In time they hope to put themselves out of business.

This, then, may be regarded as the main cleavage in 20th-century philosophy. I have, to be sure, oversimplified it. There are system builders who focus on details and analysts who seek to put together small things into a bigger thing. Moreover, between the hedgehogs and the foxes there is a middle species which aims to bridge the gap—notably the pragmatic school of Charles Peirce, William James and John Dewey.

Among the great system builders of the past were Plato, Aristotle, Descartes, Locke, Hume, Kant and Hegel. Hegel is of particular interest because this "enormously muddled but brilliant German professor of the 19th century" most profoundly affected the philosophy of the 20th century. Today he has few disciples but many offspring—most of whom deny him. As White points out, not only did Hegel "influence the originators of Marxism, existentialism and instrumentalism —now three of the most popular philosophies in the world—but at one time or another he dominated the founders of the more technical movements: logical positivism, realism and analytic philosophy." Hegel regarded the universe as the unfolding of a "World Spirit" or "Absolute." The Absolute manifests its will by a process called the "dialectic"—a kind of triadic ballet of thesis, antithesis and synthesis, ruled by a special sort of logic which controls the pattern of change and development. It is by this curious mode of locomotion—like that of a sea serpent making and dissolving its great loops as it advances—that history slithers on, that knowledge grows, that the Absolute journeys toward its fulfillment. Hegel shaped the course of modern history as well as philosophy; his system provided a scaffolding for religious belief, thereby attracting those "who could not accept atheism or Kant's peculiar agnosticism"; he encouraged the feeling, which today reigns in science as well as other branches of thought, that "there are modes of explanation other than those available in Newtonian mechanics." Hegel straightened out some things, but he turned many more upside down. Thus he made work for the philosophers who came after him.

The hedgehogs represented in this book are Benedetto Croce, George Santayana, Henri Bergson, Alfred North Whitehead, Edmund Husserl and Jean-Paul Sartre. Croce, who died in 1952 at the age of 86, was Italy's most distinguished philosopher. He was what philosophers call an idealist, which is not easy to define beyond saying that idealists assign to ideas the highest kind of existence. What is real is what is in our heads; button hooks and chairs are in a doubtful category because their existence is demonstrated only in mental activity. Two elements enter into our judgment about anything: an immediate awareness or experience, and a linking of this experience with others like it to form abstractions or concepts. This is the sum total of our knowledge; if these elements are removed, the supposed world of substance vanishes. In his principal work, *Philosophy of the Spirit*, Croce applied his doctrines to esthetics,

logic, economics, ethics and history. His most striking conclusion was that since history "is the concrete study of the spirit, of life, of human activity" it is identical with philosophy itself.

The cult of history, which would not have been altogether displeasing to Hegel, provoked a strong reaction in Santayana, the Spaniard who for many years taught at Harvard and then became an expatriate. In his outlook moral philosophy occupied the central position, and history was no more than a "servile science." The main theme of his five-volume *The Life of Reason* is the "transformation of man's natural impulses into high ideals." Man strives to live the life of reason, which reaches its highest expression in religion, art and science. Santayana was a brilliant writer. The suavity and elegance of his prose is in fact a little benumbing. One is apt to agree with what he says without knowing exactly with what one is agreeing. Bertrand Russell compared Santayana's style to the patent leather boots he wore: too smooth and polished.

Another leading figure who produced hypnosis by eloquence was Bergson. He cannot, however, be flippantly dismissed, any more than Santayana can. Bergson was as important for what he said that was foolish as for what he said that was sensible. He was an "outspoken irrationalist," a relentless foe of "scientism," positivism and materialism. This explains the immense popularity he enjoyed among artists, writers, religious thinkers and others who feared that mechanistic philosophies would destroy the values they cherished. Similar antirational tendencies are resurgent today. Some biologists are busy locating spirit in organism, some physicists see God in the harmony of certain natural constants and some psychiatrists get into bed with German theologians. The key words of the Bergsonian philosophy are *"élan vital"* (the vital impulse), "enduring" and "creative evolution." The intellect, he felt, is good in its way but not in all weathers. Science is dependable only when it deals with the inert. When it undertakes the study of life, it furnishes, at best, pale, geometric images drained of the uniqueness and originality of life itself. Life is to be lived, not merely thought about or known; the heart as well as the mind must play a part. In enduring we prove and fulfill ourselves; in elevating intuition and instinct over intellect we penetrate to the *"real* reality." Evolution is creative precisely because it is more than mechanical, because there is room in it for "real change and real freedom, unhampered by causality and determinism." Enthralled crowds, including "fashionable ladies," flocked to hear Bergson's lectures at the Collège de France. William James greeted the appearance of Bergson's *Creative Evolution* with "ecstasy." Russell was less thrilled. Anyone looking for evidence to support Bergson's restless view of the world, he said, "will find, if I am not mistaken, that there is no reason whatever for accepting this view, either in the universe or in the writings of M. Bergson."

Whitehead belongs in the company of Croce and Bergson, though, as White points out, this grouping would not have been foreseeable 30 years ago. Until then he was known for his work in mathematics and logic, for his stupendous collaboration with Russell on the *Principia Mathematica* and for his profound studies in the philosophy of science. But in the mid-1920s he crossed over to the metaphysical side. He repudiated the tradition he had done so much to further, and turned his thoughts to religion, education, morals, history and the "dark and difficult notions of intuition and organism." He scoffed at clarity and precision, of which he had once been an apostle. One of his basic ideas was that Nature is alive. Bergson had been content to say that a part of Nature—the most important part—is alive and that a true philosophy has to recognize the fact. Whitehead went further. He deemed it absurd to regard *any* part as dead: "All ultimate reasons are in terms of aim at value. A dead Nature aims at nothing."

Many acute thinkers have despaired of understanding Whitehead's philosophy. White finds it easier to explain what he was *against* than to expound the positive features of his system. "Basically," writes White, "it is the view that Nature is composed of permanent things, bits of matter moving about, as he says, in a space otherwise empty, each one having its shape, its mass, its motion, its color, its smell. It is the view of the great thinkers of the 16th and 17th centuries, the view of the ordinary man today, and according to Whitehead it has never been successfully excluded from the minds of scientists even though science has thoroughly discredited it." Modern science has made it clear that there is no empty space, but only fields of force; that neat packets of matter are a fiction; that matter is energy and energy "incessant activity." Everything therefore is an "event." All events are intertwined, and when a leaf trembles the universe shakes. Whitehead's universe is a universe of becoming and perishing, of

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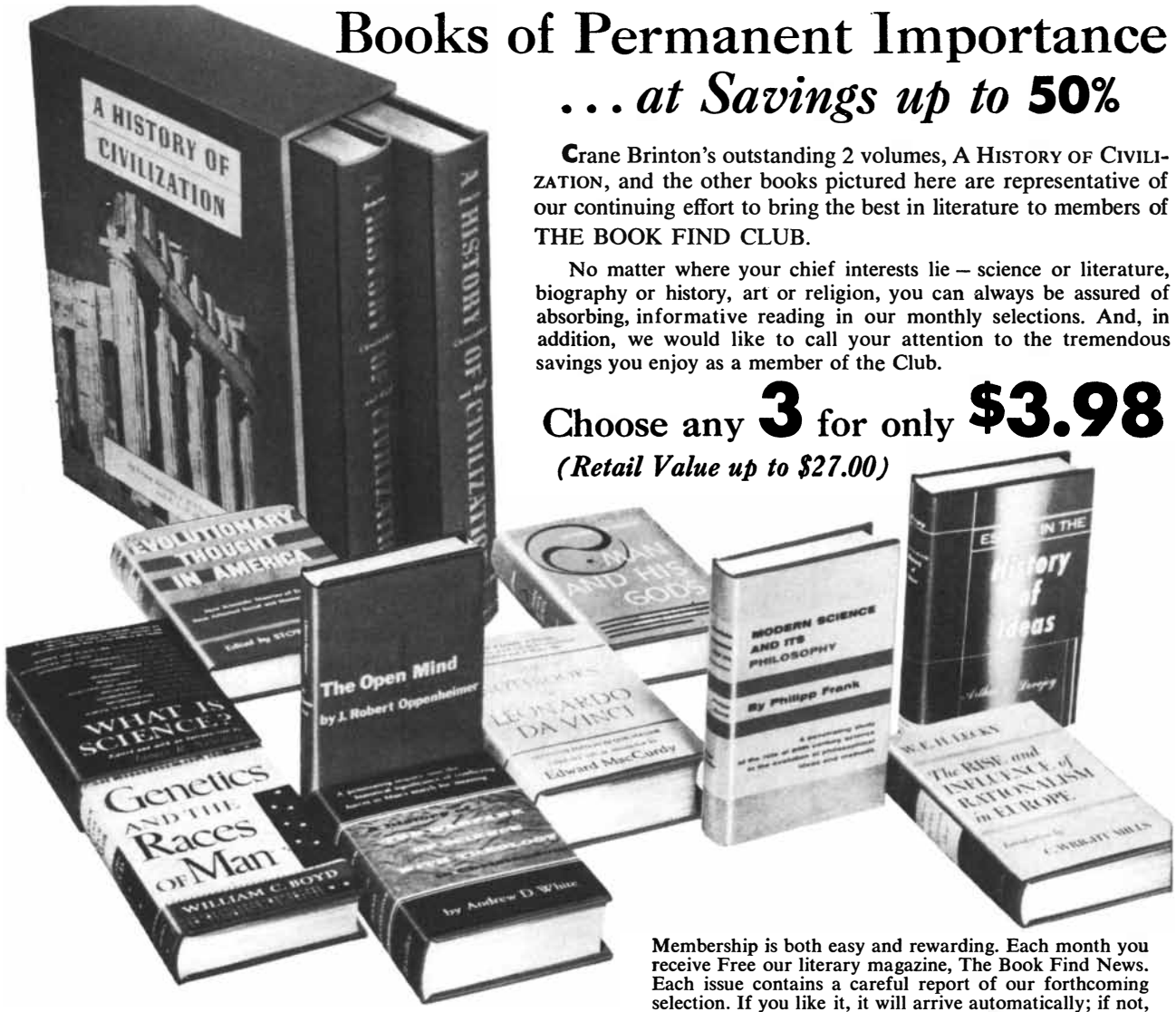

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"creative advance." It is not necessary fully to grasp Whitehead's meaning to realize that his system transforms scientific insights into a comprehensive philosophy of man and spirit.

I pass quickly over Husserl, the German phenomenologist, and Sartre, the distinguished French literary man, critic and philosopher. Husserl's ideas are to me peculiarly opaque. Sartre's existentialism (which owes much to the Danish theologian Soren Kierkegaard, and was anticipated in the writings of Dostoevski, Nietzsche and Kafka) takes many forms. One can be a Catholic existentialist or an existential atheist (like Sartre himself) or somewhere between. Existentialism is peculiarly appealing to those who see ethical ideals lying in ruins and seek solace in a categorical imperative of absolute personal responsibility for conduct. To me existentialism seems a creed rather than a full-grown philosophy.

In the middle ground between those who build systems and those who merely analyze stood the famous American trio of pragmatists: Peirce, William James and Dewey. The first was the philosopher of science, the second the philosopher of religion, the third the philosopher of morals. James once made a celebrated division of philosophers into the "tender-minded" and the "tough-minded." Peirce was tough-minded. He was original, wayward, prickly, unsuccessful—as White says, "a brilliant unemployable who had to be befriended by saintly people like William James." He introduced into philosophy the word "pragmatic," which comes from a Greek word meaning "action" and is the source of our words "practice" and "practical." Peirce conceived the main task of pragmatic philosophy to be the clarification of meanings of words as they are used by scientists. Take, for example, the word "hard." To specify its meaning and make sure it always means the same thing, we must define it by translating the sentence "This is hard" into something like "If one were to try to scratch this, one would not succeed." In general all descriptive statements in science should be translatable into an if-then form: "If operation O were to be performed on this, then E would be experienced." Any term, however well established, that resists this approach is meaningless. If any two terms yield the same translation, they are the same, however different they may appear. Peirce said that "the whole function of thought is to produce habits of action." If we respond to a word in the way Pavlov's dogs responded to a dinner bell, the word is doing its job; otherwise not. One of his famous rules reads: "Consider what effects, which might conceivably have practical bearings, we conceive the object of our conception to have. Then, our conception of these effects is the whole of our conception of the object."

James's mind was more tender than Peirce's. He had had things easier. Also he was a fuzzier thinker, but I think deliberately, just as the later Whitehead preferred fuzziness. He wrote a great work on psychology, was interested in the individual and reflected deeply on the foundations of belief and the pragmatic theory of truth. For James there was no finality in truth: it was empirical and changed as men changed. He suggested that the best we can hope to arrive at is "probable truth." But this is to be tested not by principle or dogma or "skinny" abstractions but rather by "what works best in the way of leading us, what fits every part of life best and combines with the collectivity of experience's demands, nothing being omitted."

Dewey was more concerned with social problems than was James or Peirce. He detected in James's test of truth a certain "capriciousness." His philosophy, called instrumentalism or experimentalism, took an ethical stand which he hoped would mediate between the ethics of "transcendental eternal values" and the view that value is determined "by mere liking, desire or enjoyment." Dewey's influence has been beneficent in many fields. But many philosophers do not regard him as a thoroughly original thinker: they complain that he was turgid and prolix, and that his ideas do not have that special unlocking, liberating quality which marks a first-rate philosophy.

The pragmatists traveled more than half way from metaphysics to analysis. Peirce considered metaphysics as in the nature of a sunken reef—one ought to know about it so as to steer clear of it. In the forefront of those who have tried to steer philosophy away from the reefs of idealism is the famous English philosopher G. E. Moore. Moore is a realist, an apostle of common sense and a founder of the analytic movement. Among his major pupils are Bertrand Russell, Lord Keynes and Ludwig Wittgenstein; all were profoundly influenced by him.

The heart of Moore's philosophy is the belief that the world is made up of an infinite number of independent entities, all equally "real." Where others had established hierarchies of existence and of qualities, Moore saw a world in which "*everything* is real that common sense, uninfluenced by philosophy or theology,

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supposes real." Thus there is a place for stones and for the square root of 2; for the redness of berries and the concept of good; and no one need doubt that there are trees standing in the Quad even when no one is looking. Keynes was enthralled by the "beauty of the literalness of Moore's mind, the pure and passionate intensity of his vision, unfanciful and undressed up." A simple, childlike, repetitive quality characterizes Moore's style—and an extraordinary lucidity and austerity. When he makes a point about the meaning of the universe, neither a philosopher nor a greengrocer can fail to understand; this, if nothing else, distinguishes him from other great thinkers. It also helps to fix his place in the analytic movement, for he emphasized the importance of intelligibility, of fixed points of reference for language, of basing knowledge on something more than internal fumes.

The largest and most imposing figure in modern philosophy is Bertrand Russell. He began as a follower of Hegel, abandoned Hegel's doctrines to embrace Moore's realism and then gradually relinquished Moore's view as he became more and more interested in analysis. He approached philosophy as a mathematician and logician, where Moore had come to it "more like a precise philologist with an extraordinary ear for ordinary language." Of Russell's attitude White says: "Instead of thinking of mathematics, physics and common sense as axiomatically untouchable, instead of conceiving philosophy as essentially spectatorial or passive *vis à vis* these more solid parts of knowledge, Russell insists that the philosopher should enter science and participate in the reconstruction of its foundations."

Russell's most signal success in this cleanup job was in demonstrating how mathematics can be derived from logic. The task involved, among other things, extensions and reformations of logic itself and an assault upon certain logical puzzles and paradoxes which had plagued philosophers since antiquity. In the course of his labors Russell made up a few delightful and distressing puzzles of his own which served to emphasize how badly a reconstruction of logical foundations was needed.

While Russell has little use for the doctrines of such system builders as Bergson or Santayana or Croce, and while he has engaged in a "long polemic" against pragmatism, his own conception of the role and method of philosophy is in some ways linked with both these tendencies. He has insisted that philosophy must meddle in science and other

activities as a critic, and must also be an independent discoverer of truth. In attempting to reform mathematics and physics he re-evaluated and redefined the meanings of terms "in a way that is surprisingly pragmatic." A great part of philosophy, says Russell, "can be reduced to something that may be called syntax." Although he regards as overstatement Rudolf Carnap's view that all philosophical problems are merely problems of syntax, Russell stresses the "very great utility" of the syntactical method. An example of its utility involves what is called the theory of description. Russell observes that phrases used to identify persons or things by some property rather than by name have given a lot of trouble in philosophy. "Suppose I say 'The golden mountain does not exist,' and suppose you ask 'What is it that does not exist?' It would seem that, if I say 'It is the golden mountain,' I am attributing some sort of existence to it. Obviously I am not making the same statement as if I said 'The round square does not exist.' This seems to imply that the golden mountain is one thing and the round square is another, although neither exists. The theory of description was designed to meet this and other difficulties." By means of the theory Russell was able to convert descriptive phrases into a form which cut through the existence question. Thus "The golden mountain does not exist" became "There is no entity c such that 'x is golden and mountainous' is true when x is c, but not otherwise." It is important to point out that such puzzles are in fact more than puzzles, and that their solution, involving as it does the elimination of errors in the use of language, has a profound bearing upon correct reasoning in all branches of thought.

Logical analysis, having sharpened its teeth on these puzzles, turned to chew upon concepts and problems of meaning in relativity theory and quantum mechanics, in psychology and in other sciences. There is, to be sure, less than universal approval of what has been accomplished in these forays into areas outside mathematics and logic, but the essential point is that the followers of logical analysis refuse to be awed by such problems, refuse to believe that there is some "higher" way of knowing. Russell concerns himself as fully with the problems of human society—ethics, politics, education and so on—as with the problems of technical philosophy. But he has emphasized the opinion that philosophy is after truth, that it is not concerned with promoting "good behavior" or happiness on the basis of fixed

preconceptions, and that there are many questions of profound human importance which are either unanswerable or lie outside the province of philosophy.

Carnap and Wittgenstein are considered in the two concluding chapters of White's survey. Carnap, a prominent logical positivist, holds that "philosophy is nothing but the logic *of* science," and only mathematical and empirical statements are meaningful. A statement about the universe, on the one hand, has to be reducible ultimately to "observable predicates," and has to be "verifiable" by some accepted experimental procedure; a mathematical statement, on the other hand, is, if true at all, *a priori* true—which is to say, true independently of experience. Thus mathematical statements are tautologous: they assert nothing more than what is asserted in a statement of the type "All spinsters are unmarried." It must not be supposed that the insistence of the logical positivists on precise categories of inquiry, verifiability and the like cuts them off from questions of broad human concern. They are not indifferent to the study of ethics, for example, but their interest is confined to empirical investigations of the causes and effects of human behavior and does not extend to norms of action or moral judgments.

Wittgenstein, a strange, lonely, moving figure, represents the extreme of the logical positivist position. He was an almost fanatical apostle of clarity of meaning, but he himself spoke in dark, aphoristic riddles, often as difficult to fathom as the sayings of Heraclitus. He regarded all philosophical statements as meaningless, all metaphysics as a disease. He tried to explain the origins of this disease and how to heal it. His most famous slogan was "The meaning is the use" (which recalls Peirce); another of his aphorisms was: "The riddle does not exist. If a question can be put at all, then it *can* also be answered." Wittgenstein succeeded to Moore's chair in philosophy at Cambridge. He was much influenced by Russell. Today his own influence is at its height, chiefly as the result of the appearance of his posthumous work *Philosophical Investigations*. Since Wittgenstein regarded philosophy as nonsense, one may ask how he justified his own. The answer is that he didn't. At the end of his celebrated book, the *Tractatus*, he spoke of his propositions as "senseless" but serving the purpose of a ladder. They were useful only to enable a reader to climb to a better view; having gained this, the reader was enjoined to throw the ladder away. Carnap and other logical positivists have felt that

Wittgenstein's disclaimer went too far: they say that his system does make sense—an understandable position since they are his followers.

White's book has its weak points. He does not explain all systems equally well (he is, of course, under considerable pressure to explain in a book of 250 pages the doctrines of no fewer than 14 philosophers). Nor is he an unbiased reporter. His attempt in a final chapter to reconcile the hedgehogs and the foxes is singularly unconvincing. Nevertheless we are much in his debt for his survey of the two main viewpoints in philosophy—synoptic and nearsighted. White is a skilled and witty guide, and he has furnished an excellent introduction to a lively, exciting and contentious period in the history of philosophy.

Short Reviews

THE FABULOUS PHONOGRAPH, by Roland Gelatt. J. B. Lippincott Company ($4.95). In its issue of December 22, 1877, SCIENTIFIC AMERICAN ran the following item: "Mr. Thomas A. Edison recently came into this office, placed a little machine on our desk, turned a crank, and the machine inquired as to our health, asked how we liked the phonograph, informed us that *it* was very well, and bid us a cordial good night. These remarks were not only perfectly audible to ourselves, but to a dozen or more persons gathered around." The phonograph dates from the autumn of 1877, but Edison was not its only inventor. On December 5, 1877, the French Academy of Sciences was informed of another sound-reproducing device, which used a disk and traced the sound waves on lampblacked glass, as opposed to Edison's cylinder and tinfoil. Its inventor was Charles Cros, "a minor poet, amateur scientist, friend of Verlaine, Banville and Manet." The beginnings and development of the phonograph, from tinfoil to hi-fi, are set forth most readably in this book by Roland Gelatt, an editor of *High Fidelity* magazine and well-known writer on music and records. The author describes, among other things, the technical contributions of Emile Berliner and Eldridge Johnson, Caruso's fabulous recording career, the advent of jazz disks, the resulting multiplication of phonographs from 27 million in 1914 to 158 million in 1919, the twilight of the phonograph during the depression and its later renaissance.

MERCHANT SHIPS: A PICTORIAL STUDY, by John H. LaDage, with Charles L. Sauerbier, George N. Steiner, Moses

W. Hirschkowitz, Alfred E. Fiore. Cornell Maritime Press ($15.00). Five experts have collaborated to produce this excellent book on every type of passenger and cargo vessel from Hog Islanders and superliners through double-ended ferries and derrick barges. Anything you could conceivably want to know about a ship is to be found in this compendium. It includes information about the *United States* and the *Queen Mary*; the damage caused by collisions, corrosion and sea organisms; the care, repair, building and rebuilding of ships; the booby hatch (which gives access to stores below the forecastle deck); the wind dodger (which protects the bow lookout); Suez Canal davits; watertight doors and meccano decks; the poop deck, the escape trunk and the triple-roller chock; kingpost shrouds; bilge pumps and Butterworth machines; the nun buoy (a buoy that looks like a nun); the "trick" wheel (an emergency steering device). The book is indispensable for professionals and fascinating for anyone who cares for an ocean wave.

MEDICAL RESEARCH: A MIDCENTURY SURVEY, edited by Esther Everett Lape and associates. Little, Brown and Company ($15.00). This large, two-volume work, sponsored and prepared by the American Foundation (established by Edward Bok in 1924), is a report on U. S. medical research and clinical problems. The editors cover a broad field. They examine in the first volume such topics as medical education, the contributions of the physical sciences and mathematics to biological and medical research, the scope of clinical research, the organization and financing of research, the relations between government and science and problems of communicating scientific results. The second volume discusses nine major unsolved clinical problems, including cancer, infertility, arteriosclerosis, hypertension, virus diseases and schizophrenia. The editors stress the importance of basic research. Their comprehensive work attempts to cover so much ground that the treatment of some topics, especially in the social and economic sphere, is superficial. Also, it is astonishing that the editors have put out a 1,500-page study without an index. Despite these and other failings this is an invaluable survey—richly informative, clear, progressive in outlook.

TINKERS AND GENIUS, by Edmund Fuller. Hastings House ($4.50). This is an anecdotal account of the works, woes, adventures and successes of sundry

Yankee inventors. The subjects include David Bushnell, who invented the revolutionary submarine called the *Turtle*; Benjamin Franklin, among whose casual and lesser contrivances were a precursor of the mimeograph, bifocal glasses, a rocking chair with a built-in fan worked by a pedal, an open stove for the warming of rooms; "poor John Fitch," the ill-fated steamboat innovator; Robert Fulton; Eli Whitney; Tom Paine, who deserves remembrance for his iron bridge as well as his political and philosophical writings; Amasa Goodyear, a man peculiarly obsessed with rubber; Nathaniel Bowditch, who blended a passion for the sea and for logarithms into a great work on navigation. A diverting hodgepodge.

THE ORIGIN OF VERTEBRATES, by N. J. Berrill. Oxford University Press ($4.00). Described as in a sense "a venture in science fiction," this book is an attempt to trace man's ancestry to the "far distant prechordate and prevertebrate past of our own lineage." The author speculates agreeably and learnedly on Cambrian and Precambrian happenings, in particular on the possibility that man is a direct descendant of the ancient, efficient marine creature known as the sea squirt. For a professional biologist who can follow his technically intricate and imaginative reconstructions, Berrill's essay should prove enjoyable and stimulating.

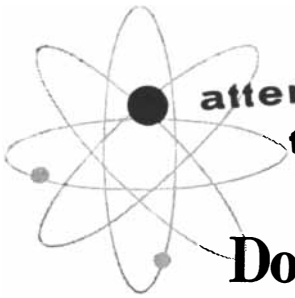
SOLAR ENERGY RESEARCH, edited by Farrington Daniels and John A. Duffie. The University of Wisconsin Press ($4.00). If only a small fraction of the effort devoted to work on atomic energy were expended in research on solar energy, significant progress could be made, says Professor Daniels in his introduction to this symposium. But since solar energy has no obvious military utility, the necessary funds and scientific manpower are not easy to come by. In any case the 31 contributors here make out both an interesting and a challenging case for paying greater attention to the sun. They consider space-heating and domestic uses of solar energy, the heat pump, small solar power plants, solar evaporation and distillation, conversion of solar to electrical energy, solar furnaces, photosynthetic and photochemical utilization of solar energy.

THE WORLD WE LIVE IN, by Lincoln Barnett and the editorial staff of *Life*. Simon and Schuster ($13.50). The well-known 13-part serial which appeared in *Life* magazine from 1952 to 1954 is here put together in book form. The subject

is the physical history of the earth, from crossopterygians to curved space. Of the countless illustrations—paintings, photographs, drawings—some are stunning, some surprisingly dingy.

THE SCROLLS FROM THE DEAD SEA, by Edmund Wilson. Oxford University Press ($3.25). DISCOVERIES IN THE JUDAEAN DESERT, by O. P. Barthélemy and J. T. Milik. Oxford University Press ($10.00). The wide interest excited by the 1947 discovery, by a young Bedouin goatherd called Muhammed the Wolf, of the manuscripts now generally known as the Dead Sea Scrolls is reflected in an extensive and fast-growing literature of which these two volumes are recent examples. Wilson's book, a slightly longer version of his three articles in *The New Yorker*, is addressed to the general reader. It describes the finding and perilous peregrinations of the Scrolls, the fascinating textual, historical, archaeological and religious questions which they raise, the personalities involved in their restoration and interpretation. Wilson, primarily a literary critic, who is acting here as a reporter of the opinions of experts, has achieved a good grasp of this complex field of scholarship and its intricate problems. It cannot be said that he has made every aspect of the subject clear. Indeed, his attempt to unravel the identity of the ancient figure referred to as "the teacher of righteousness" snarls more knots than it unties. Still, he has written an engrossing book. The Barthélemy-Milik monograph is the first of a series on the authors' studies of the Scrolls and other objects excavated from the Qumran cave—textiles, pottery, coins and literary and commercial documents. The book has many plates and other illustrations.

THEODORE ROOSEVELT'S AMERICA, edited by Farida A. Wiley. The Devin-Adair Company ($5.75). This new volume in the American Naturalists Series consists of selections from Teddy Roosevelt's extensive writings on his outdoor adventures—as a rancher in the Dakota Bad Lands, as a sheriff in the Wild West, as a hunter in Africa, as an explorer in South America. He was not much of a botanist, nor was his interest in the countryside and its fauna primarily scientific. It was conflict and mastery that exhilarated him; he treated nature as if it were a big-business trust or San Juan Hill. Nevertheless he was a remarkably keen and sensitive observer, and an unfailingly interesting writer. The selections in this book have been well chosen; they whet the appetite for more.



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THE AMATEUR SCIENTIST

Mostly about the investigation of electrical discharges without expensive vacuum pumps

Nearly 200 years ago William Watson, an English physician who loved to tinker in fields in which he was an amateur, tackled a fundamental question that was bothering all the great minds in the newly discovered field of electricity. An electrified body, it was observed, gradually loses its charge, no matter how well it is insulated. How does the charge escape? Is it carried off by the surrounding air? Watson made an experiment which he hoped would settle this question. He sealed two wires in a glass bulb, leaving a gap between them, and applied a voltage across the gap. Then he began to evacuate the air from the bulb with a pump. If the leakage of charge across the gap declined as the air was removed, he would have demonstrated that air could indeed carry electrical charge. But to his dismay, the leakage actually increased as air was evacuated from the bulb. What was even more mystifying, when he had removed most of the air the bulb suddenly became filled with a pink glow that danced and shimmered like the Northern Lights.

Watson, not realizing that a gas becomes a better conductor of electricity as its pressure is lowered, considered his experiment a failure. He named his bulb the "aurora tube" and bequeathed it to the world as a curiosity. Actually it is doubtful that any phenomenon found in nature has been more fruitful than Watson's discovery of the glow discharge. It gave rise to multitudes of experiments by thousands of physicists. Modifications of Watson's tube—cathode-ray tubes—led Wilhelm Roentgen to the discovery of X-rays, J. J. Thomson to the discovery of electrons and John Fleming to the invention of the radio tube. More recent versions of the tube have become familiar in the shape of neon signs, Geiger counters, fluorescent lamps, voltage regulators, counting tubes for digital computers and many other gadgets.

Forrest H. Frantz of Mississippi State College, a physicist who has made a specialty of investigating varieties of these tubes, observes: "We can discern no end to these remarkable diggings. The more we work them, the more pay dirt we strike. Within the last 10 years one branch, which has to do with the leaky insulators called semiconductors, yielded the transistor, a device which may well open a whole new era of technology. Another promising line of work going on now has to do with the way electrons are emitted by electrodes shaped into exquisitely fine points [see "A New Microscope," by Erwin W. Müller; SCIENTIFIC AMERICAN, May, 1952]. Another branch is the micro-gap—a pair of closely spaced electrodes which behave in unexpected ways when a voltage is applied across them. An amateur who has not checked into electrical discharges, particularly glow discharges, is missing out on a chance for some fascinating experiments.

"One of the first to make real headway in the field of glow discharges was the French physicist J. P. Gassiot. By introducing traces of individual gases into the aurora tube, he produced glows of various characteristic colors. Neon gave an orange glow; hydrogen, crimson; mercury vapor, violet, and so on. Gassiot's work was one of the stepping stones toward modern spectroscopy.

"The great popularizer of the glow discharge was an amateur—the German Heinrich Geissler. By profession he was an instrument maker, but his name is remembered for his work on discharge tubes. He made them in such profusion and in so many intriguing shapes and forms that they are known as 'Geissler tubes.' It seems ironic that he should be known as the father of neon advertising signs while the name of Masson, their discoverer, goes almost unmentioned.

"By 1869 it was clear that rarefied gas conducts better than gas under pressure for the reason that molecules have greater freedom of movement in a partial vacuum. But if the last molecule could be removed from a tube, the conduction should, it was reasoned, drop to zero. Johann W. Hittorf of Germany built a really good air pump in order to confront this theory with a conclusive test. Although the pump did not achieve the primary objective, the by-products of the experiment assured Hittorf a lasting place in the history of science. As the pumping progressed past the stage where the characteristic glow appeared, Hittorf observed near one of the electrodes a dark region which grew larger as the pressure dropped. He also noted a strange fluorescence that lighted the walls of the tube behind the positive electrode. He suspected that the fluorescence was excited by rays emitted from the negative electrode. To test this, he sealed a small cross of lead inside the tube between the cathode and anode. It cast a shadow. As we now know, it was blocking a stream of electrons coming from the cathode. Here was the primitive beginning of television!

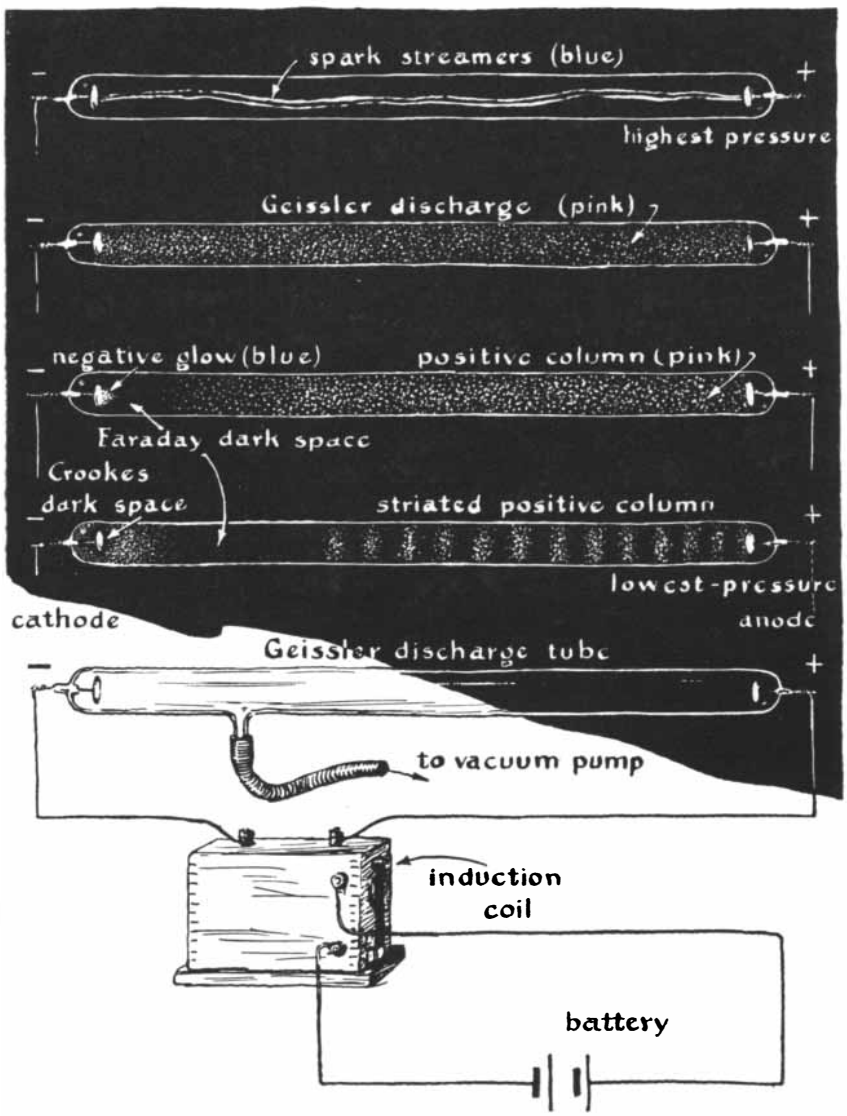
"The behavior of electrical discharges through a gas is influenced by many factors which can be adjusted to produce a dazzling variety of effects. The most important variables are: the pressure of the gas in which the discharge occurs, the type of gas, the size of the gap between the electrodes in the tube, the details of the electrical circuit, the cathode material, the shape of the electrodes and the voltage across the gap.

"Not all these elements can be conveniently controlled in a home-built apparatus. Probably the easiest to play with is the pressure. To duplicate the effects pictured here [*see drawing on the opposite page*] you will need a 12-inch glass tube with electrodes sealed in, a fair vacuum pump and a high-voltage source. The tube can be bought at a scientific supply house. The pump, which may be a mechanical one of the piston type, is not difficult to build, but the piston and valves must be fitted closely and should be sealed with a good grade of stopcock grease. The necessary voltage (about 15,000 volts) can be obtained from an induction coil as shown. A direct-current machine would be pref-

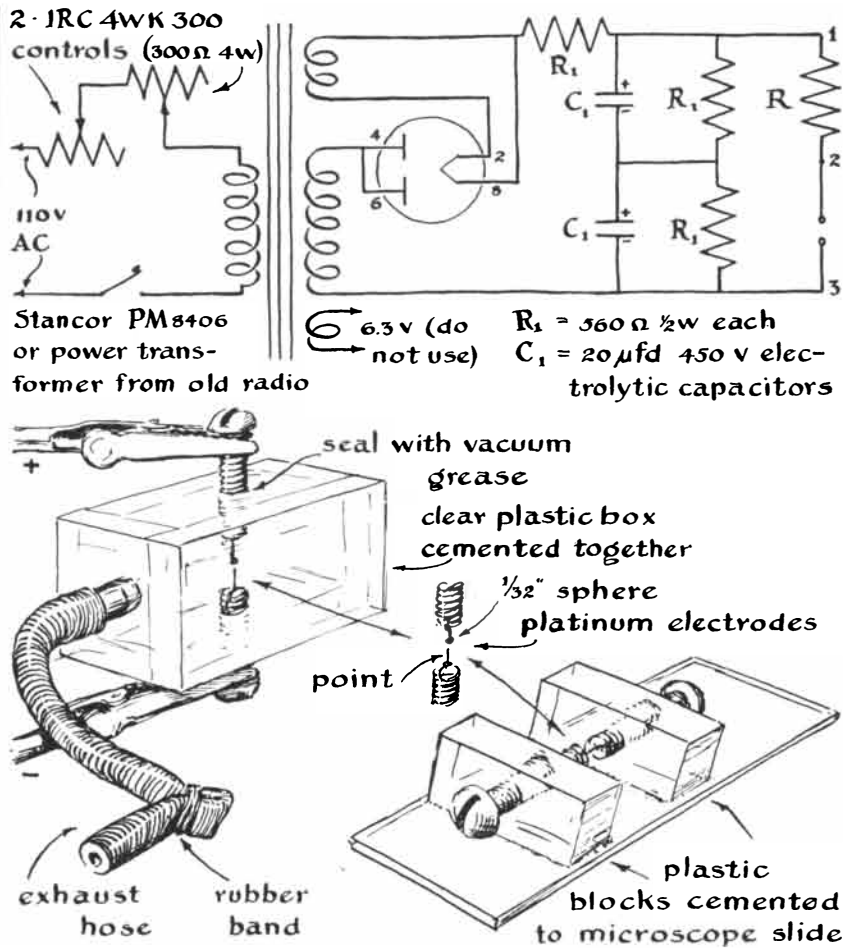
erable, because the pattern of the glow is determined by the direction in which the current flows, but such machines are expensive. For casual observations an induction coil will do. It produces an alternating current, but with a much stronger surge in one direction than the other. The strong voltage pulses come fast enough so that the discharge will appear steady although it is actually intermittent.

"It is interesting to apply a constant voltage to the electrodes of the tube and observe the results as the pressure is progressively lowered.

"If the experiment is performed in a fairly dark room, you will see the glow of the corona discharge around the electrodes when the voltage is applied. Then, as the pressure drops, occasional spark streamers crackle across the entire gap. These are like extremely thin lightning flashes. When the pressure gets down to about a hundredth of an atmosphere, the streamers appear continuously and in great numbers. Shortly thereafter the sparks give way to a silent glow—the pink of the aurora, sometimes called the Geissler discharge. With further lowering of the pressure the pink glow pulls away from the cathode, leaving a bright bluish glow next to the cathode and a dark space (known as the Faraday dark space) around that. As you continue to pump, both the 'negative' (bluish) glow and the Faraday dark space expand at the expense of the pinkish region that fills the rest of the tube. Next the negative glow separates from the cathode, leaving a second dark



Characteristic effects observed in Geissler tubes



Micro-glow discharge gaps and circuit details

space (the Crookes dark space) and an orange-colored luminous sheath (the 'cathode glow') around the cathode. Simultaneously the pinkish glow breaks up into a series of separate vertical stripes. At still lower pressure the Crookes dark space grows until it pervades the entire tube. To a casual observer the cathode glow seems to make physical contact with the electrode. Actually it floats a fraction of an inch above it. In between is still another dark space called the Aston dark space. At the other end of the tube a similar 'anode' dark space separates the anode from the anode glow, which takes the form of a bright, thin striation at the extreme end of the positive column.

"The various effects, as they appear, give an approximate idea of the pressure of the gas in the tube. The noisy spark streamers change into the silent pink glow when about 90 per cent of the air has been removed. The pressure is then just enough to support a column of mercury 80 millimeters high. (At sea-level atmospheric pressure, air supports 760 mm. of mercury). At a pressure of nine mm. the brighter glow appears at the cathode and anode. Current through the tube increases sharply at this point, as you can observe by placing an ammeter in series in the circuit. The positive column appears at about five mm., along with the negative glow. Striations begin to break up the column at one mm. The glass walls of the tube fluoresce at one-half mm. under the bombardment of electrons from the cathode. The Crookes dark space appears at one-quarter mm. and begins to cut into the positive column seriously at one-tenth mm. The negative glow vanishes at one-fiftieth mm. and the anode glow at one-ninetieth mm. At a pressure of one 500th of a mm. X-ray emission begins, causing the glass walls to fluoresce again, this time with a distinctive color that depends upon the chemical composition of the glass. Often it is a pale greenish-blue. Below a thousandth of a mm., when all but a millionth part of the air has been exhausted, the electrical resistance of the gap increases sharply,

and you must use an ammeter of high sensitivity to measure the minute trickle of current that continues to flow. A piston pump should be able to reach all but the lowest of these pressures.

"If you do not have facilities for building the pump and generator, you can still experiment with glow discharges by setting up micro-gaps [*see the lower part of diagram on the opposite page*]. They exhibit some of the effects observed in large tubes—which implies that they may replace these tubes in some electronic circuits. They can also be used as microphones, as instruments for investigating aerodynamic effects and in other applications which offhand might appear beyond a device of such primitive simplicity.

"Micro-gaps operate on relatively low voltages, which can be derived from small transformers of the type used in radio receiving sets. The circuit for an adequate power supply is shown in the upper part of the drawing on the opposite page. The output can reach about 900 volts, hence the experimenter should exercise appropriate caution when working with it. The voltage is varied by means of two rheostats connected in series with the primary circuit of the power transformer.

"An enclosed gap will sustain a glow discharge across as much as a quarter of an inch of separation if the pressure is made low enough. For the pump you can use a converted automobile-tire pump. You simply reverse the piston washer and give it a thick coat of stopcock grease. The pump then sucks in air when the handle is pulled up. One sharp stroke of the pump handle will exhaust the gap sufficiently for most observations. The vacuum is maintained by clamping the hose immediately. All the characteristic effects of the larger glow discharges will appear in the little gap, but in reverse order as air leaks slowly back into the enclosure.

"The best material to use for the electrodes is platinum wire, but copper or silver will do. Both electrodes may be pointed, or the cathode may be spherical and the anode pointed. This makes it easier to align the electrodes. You can make a spherical anode by connecting two short lengths of fine platinum wire to the power supply, bringing the tips together and then separating them. The arc that forms will melt the tip of one of the wires and surface tension will draw the molten metal into a bead. To limit the arc current, a resistor should be placed in series with one of the wires. For a platinum wire five thousandths of

an inch in diameter the resistance should be 60,000 ohms. Thicker wire requires a smaller resistance.

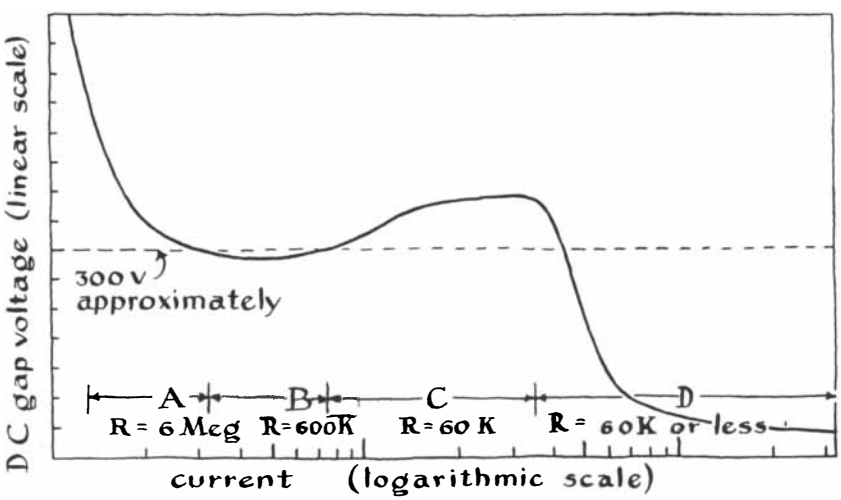
"The resistor also serves as an automatic voltage and current regulator in the completed apparatus. You need a higher voltage to start a glow than to keep it going. At the instant the switch is turned on, before a spark has jumped the gap, there is no current. The full 900 volts of the power supply are exerted across the gap. When the gap is ruptured by the spark and electricity flows, some of the available pressure is used up pushing the current through the resistor. The voltage is now divided so that there is about a 600-volt drop through the resistor and a 300-volt drop across the gap.

"The upper limit of current through the gap can be adjusted by varying the resistance. If it is 60,000 ohms, the maximum will be about 10 milliamperes. For values of 600,000 ohms and six megohms, the upper limits are approximately one milliampere and a tenth of a milliampere respectively. (You may find that radio supply dealers do not stock resistors in these values. If not, the generally available values of 56,000, 560,000 and 5.6 million ohms, in the two-watt size, are satisfactory.)

"Open gaps of the type shown in the lower right portion of the drawing on page 134 have not received as much attention as those designed for operation at reduced pressure. Their electrode spacings cannot be more than about five thousandths of an inch. Unless they are studied under a microscope, many details of the glow will be missed. My son's toy microscope in the 50× range gives satisfactory results. It shows, in addition to other details, the overheating of the cathode when the current is too high and bright flashes as bits of metal are sputtered off the cathode by positive ion bombardment.

"By adding a vacuum tube voltmeter or a sufficiently sensitive ammeter to your apparatus, you can determine the current flowing in the gap circuit. This will show the remarkable way in which the resistance of the gap varies through a wide range of applied voltage. The voltmeter measures current indirectly. You hook it across the resistor and measure the voltage drop. Dividing this figure by the value of the resistor gives the current through it, and, since the two are in series, through the gap also. It is more convenient, of course, to measure the current directly with an ammeter of appropriate range.

"An ammeter capable of measuring in the billionth-ampere range will show that current actually starts to flow whenever a voltage, however small, is applied across the gap. This current consists of electrons dislodged from the metal of the electrodes by the action of light and also of electrons knocked off atoms in the air by cosmic rays and natural radioactivity. Normally these negative particles merely bounce around in the gap at random. When voltage is applied across the electrodes, however, they are pushed toward the anode, and the movement constitutes a current. As the voltage is increased, more of them join the parade and the current grows. A point is finally reached when all that are released reach the anode; further increases in voltage then fail to produce corresponding increases in current. If the gap is now shielded from light, the current



Curve showing voltage-current relationship of micro-glow discharge

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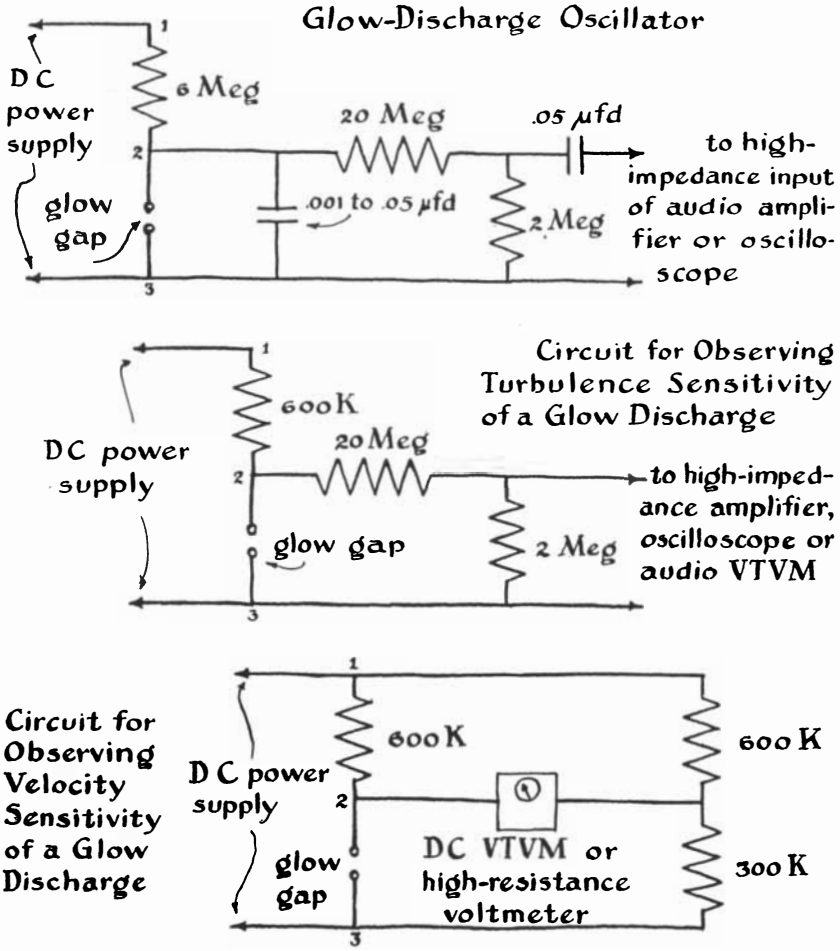

Circuits employing micro-glow discharge gaps

will drop sharply. It does not fall to zero, however, because cosmic rays and radioactivity continue to create ions. Thus in the beginning the conductivity of the gap depends on the action of light and other external radiation. It is not self-sustaining.

"As the voltage is increased further, a point is reached when the accelerated electrons acquire sufficient energy to dislodge other electrons from the gas molecules by collision. These new electrons and resulting positive ions now join the current, are accelerated and in turn acquire ionizing energy. Thus the current increases exponentially. This phenomenon is called gas amplification. Although the current represented by the original photoelectrons has been increased enormously, the conductivity of the gap is not yet self-sustaining. When the light is shut off, it will drop to near zero. This is the region of the corona discharge.

"A slight further increase in voltage will cause the current to increase faster than the exponential rate. The gap will then show *negative* resistance, which means that, as the current increases, the voltage across the gap decreases. Now current will continue to flow when the light is shut off; the discharge has become self-sustaining. Between the non-self-sustaining (dark current) region and the self-sustaining (glow) region is the region of spark discharges. These are not necessarily accompanied by the bright flash and sharp click commonly associated with sparks.

"After the self-sustaining current has started, the resistance of the gap continues to drop for a time as the voltage increases. Eventually it reverses again, increasing positively. The two points of reversal mark the boundary of the glow discharge region. A still higher voltage drives the resistance into a third and final reversal. Again the resistance value is negative. Now you have reached the region of the electric arc. The current and temperature of the gap increase enormously as the arc grows and the electrodes erode rapidly.

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various types of discharge are of the order of billionths of an ampere for the dark current region, millionths of an ampere for the corona, thousandths of an ampere for the glow and amperes for the arc. This is only a rough classification. You may, for example, get an arc discharge with a current of only one-hundredth ampere if you make the gap spacing small enough.

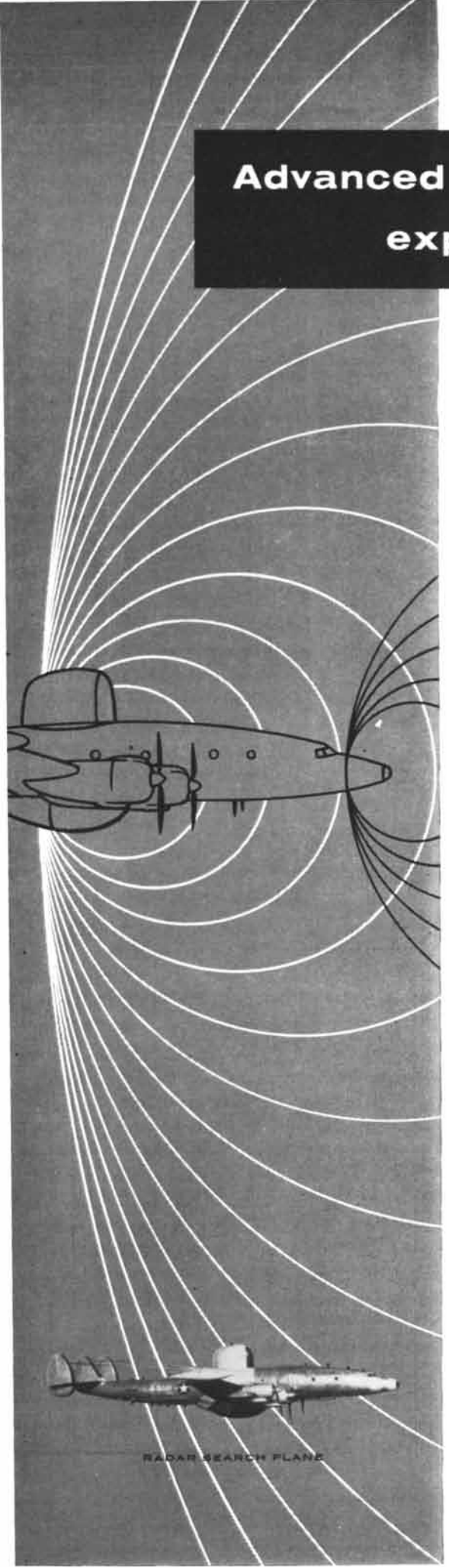
"A plot of the current-voltage relationship across a micro-gap of five thousandths of an inch in air will have the general shape of the curve in the chart on page 136. The resistances to be used for the various current ranges are shown. Observe that in the A region an increase in current causes a decrease in voltage, thus indicating negative resistance. This property is exhibited by only a few devices other than the discharge gap, notably the vacuum tube and the transistor. It is of immense practical interest.

"One of the many jobs that a negative resistance device can do is to switch a circuit on and off automatically at high speed. For this purpose it is used as a 'relaxation oscillator.' A diagram for one that employs a micro-gap as the active circuit element appears as the top diagram on page 138. In this hookup the discharge across the gap is automatically turned on and off at a steady rate.

"The frequency of the oscillator may be varied by changing the value of either the capacitor, which is connected across the gap, or the resistance. When the product of the value of the capacitor multiplied by the resistance is large, the frequency will be low; when their product is low, the frequency will be high. The resistance must be kept fairly large or the device may refuse to oscillate.

"The B portion of the characteristic curve is interesting because the voltage remains essentially constant over a relatively wide range of current. This property may be applied for voltage regulation. Gas-filled tubes are widely used in electronic apparatus for this purpose, the glow being sustained by only a few milliamperes. I have built a circuit around one of these tubes that holds the output essentially constant at 150 volts while the input varies from 275 to 500 volts!

"In the C region of the characteristic curve the gap voltage increases as the current increases. Under the microscope you can see no change in the area of the cathode covered by the blue glow, but the intensity of the glow increases. This is a region of positive resistance, and variations in the pressure of the gas will cause comparable variations in the intensity of the current. This property sug-



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The Advanced Electronics Systems Staff is concerned with all Lockheed aircraft in development and production. To the career-minded engineer, three aspects of the work are significant:

1) Assignments cover virtually every type of aircraft and weapons system; 2) personal initiative is welcomed and encouraged under the Staff's philosophy of operation; 3) the Staff is undergoing continuous expansion because of the growing importance of its work.

Expanding, long-range activities in fields of fighter-interceptors, early warning aircraft and A.S.W. patrol bombers have created a number of positions for Electronics Systems Engineers able to fill senior positions.

Openings are in the following fields:

RADAR
Duties involve developing requirements and specifications after extensive analysis for various radar, display and data handling systems. Monitoring developmental programs is also an important aspect of this position.

COMMUNICATIONS
Duties involve developing long-range communication and data link systems, studying meteorological and atmospheric features and guiding antenna design.

FIRE CONTROL
Duties involve developing requirements of airborne fighter-to-fighter and fighter-to-bomber fire control systems and monitoring programs leading to actual systems to meet the requirements. Strong experience in computer techniques is required.

NAVIGATION
Duties involve developing requirements for advanced, self-contained, high accuracy doppler and inertial systems and implementing programs to obtain these systems. Extensive experience in airborne navigational systems is required.

COUNTERMEASURES
Duties involve developing requirements and monitoring programs for advanced electronic countermeasure systems, including receivers, analyzers and jammers.

ANTENNA DESIGN
Duties involve developing requirements for communication navigation and radar antenna systems and participating in design of the systems. Most of the development work in this field is performed at Lockheed Laboratories.

Moving Allowances – Generous travel and moving allowances enable you and your family to move to Southern California at little or no expense.

Scientists and engineers interested in performing advanced electronic systems work on diversified projects are invited to write E. W. Des Lauriers, Dept. AE-12-2. Please include your home phone number.

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gests that the gap should be useful for translating rapid changes in air pressure into changes in current. It might, for example, convert sound waves into electrical impulses.

"In 1922 Phillips Thomas, a research engineer for the Westinghouse Electric Corporation, conceived the idea of putting a glow-discharge gap to work as a microphone at radio station KDKA. Having no diaphragm, it would avoid some of the resonance effects that impair the performance of conventional microphones. Thomas' microphone was used in broadcasts from KDKA for a time, but it was subject to high-frequency oscillations, noise and the disintegration of electrodes. Today, when we can take the engineering of radar and rockets in stride, these problems scarcely seem insurmountable.

"Last summer I did considerable work on adapting a glow discharge gap to detect turbulence in the air. I was trying to use it as the sensing element in a turbulence meter in our aerophysics laboratory.

"One of the major difficulties with micro-gaps is that their electrodes disintegrate rapidly. However, August Raspet, who heads our department, felt that the problem could be minimized by keeping the operating current very low, thus reducing the bombardment of the cathode. There were also other problems to be considered—oscillation, noise, maintaining the glow discharge and making the equipment small enough for airborne operation. We finally developed an experimental instrument which largely overcame these problems. It gave a reasonably stable measurement of turbulence for a period of 40 minutes—a demonstration that the micro-gap has promise of becoming a practical tool of aeronautical research workers.

"An amateur may observe the sensitivity of his micro-gap to air movements by connecting it into the circuit configuration shown at the bottom of the group of diagrams on page 138. Blowing on the gap even lightly causes a deflection of the meter.

"The circuits presented here have been simplified to make their construction as easy as possible for beginners. The simplification was achieved, however, at the expense of refinements which can compensate for some of the shortcomings of glow-discharge gaps. An amateur can easily discover clues to the cure of these shortcomings by consulting reference texts. In the course of his experiments he may even hit upon an idea that will help to advance the utility of the glow discharge."

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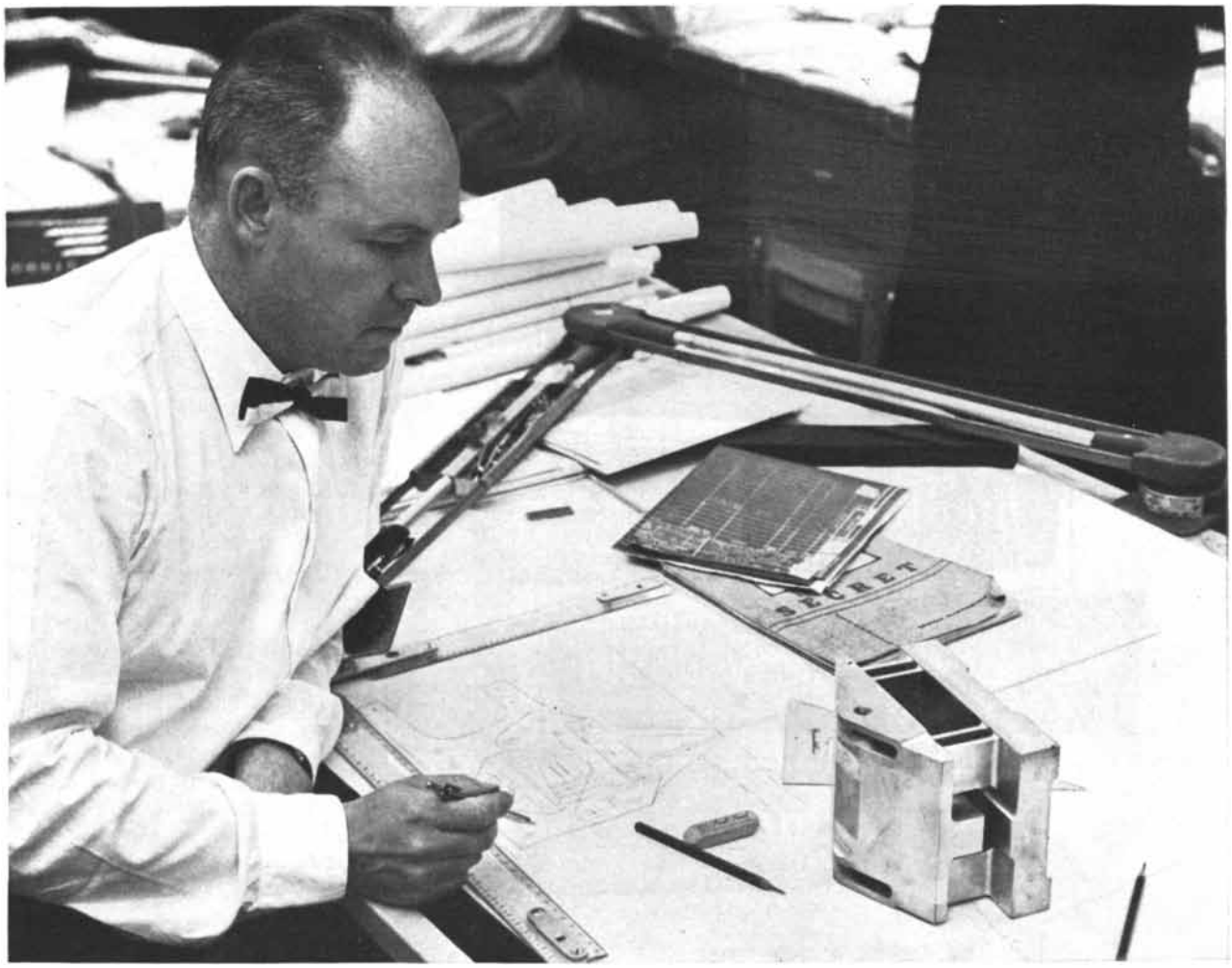

Thrust gage design is this Boeing engineer's "baby"

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The mount, called a thrust gage, must fit engine and airframe without modification of them, and must "grow" equally in all directions during a temperature rise of several hundred degrees in less than a minute. The object is a stronger engine mount with less than half the weight of the present one.

This is typical of the challenging and creative assignments given Boeing engineers. There are more than 6,000 of them—mechanical, civil, electrical, aeronautical and nuclear engineers, and mathematicians and physicists. And more engineers of all kinds are needed.

This engineer is finishing his layout, with the preliminary mockup before him. Next, he will supervise draftsmen and engineering aides in final drawings. Then he will work closely with other engineers in production, structural testing, instrumentation and telemetering. Creating this thrust gage gives him responsibility, career growth, and a real sense of professional achievement.

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SEMI-CONDUCTORS—Transistors—Semi-Conductor Devices—Materials			H	H	H	H	H	H	H	H	H	H	H	H
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COMMUNICATIONS—Radio—HF—VHF—UHF—Microwave—Telephone—Teletype—Telegraph Terminal Equipment—Wave Propagation		F	F S I	F S I	F S I	F S	F S	F S	F S	F S	F S			
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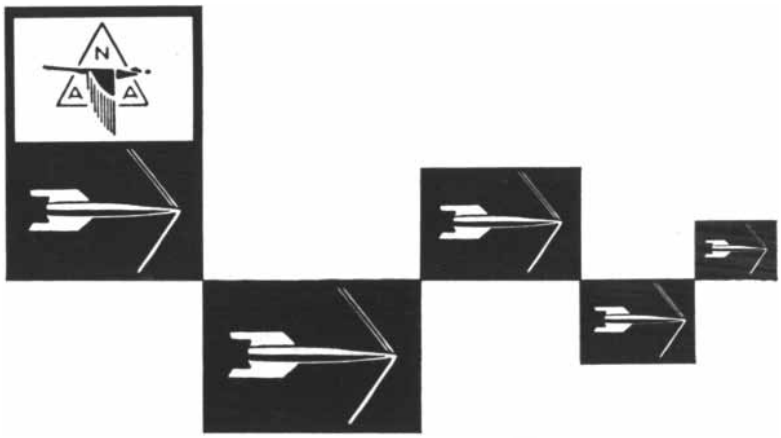

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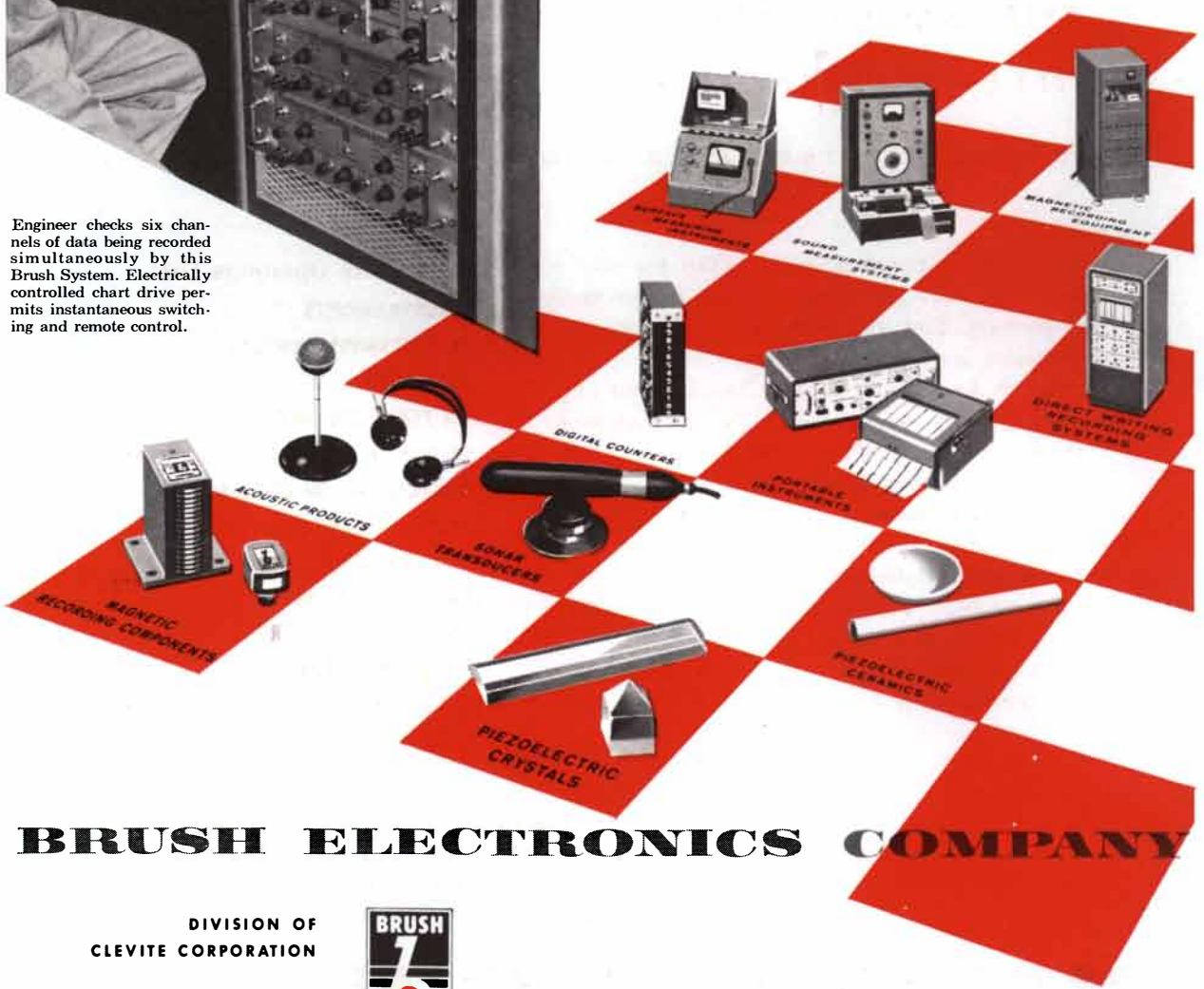

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