SCIENTIFIC AMERICAN

EXPERIMENTAL SALMON

FIFTY CENTS

August 1955

Three NEW Refractory Products For Reaction Motors

IN THIS "high temperature age," when industry is asking for materials with ever higher melting points, the requirements of reaction motors are extremely demanding.

Depending upon extreme temperature differentials in converting heat into useful work, the power plants for jet propulsion present unique time-vs.-temperature problems. To meet these problems, component materials must be able to withstand not only very high temperatures but also other factors such as thermal shock, erosion, corrosion and oxidation.

Aware of these requirements, Norton Company has for years been engaged in a program of experimentation, development and testing of various materials. A number of these have proved highly satisfactory for reaction motor and similar applications; in particular, the three described below.

ROKIDE* "A"
Aluminum Oxide Coating

A hard, adherent, refractory oxide coating, pure white in color and containing about 98.6% Al_2O_3. It has been successfully applied on ceramics, glass, and certain plastics but particularly on metals in thicknesses of .005″ to .050″, and greater in special cases. This crystalline oxide coating protects the base material under high temperatures and erosion conditions, and its alumina, being harder than the hardest steel, provides strong resistance to abrasion. ROKIDE "A" coating is thermally and electrically insulating and is slightly permeable. This coating and coating process are covered by U. S. Pat. #2,707,691.

ROKIDE "C"
Silicon Carbide Coating

This coating was developed to improve graphite components for high temperature use. It consists of a protective layer of pure CRYSTOLON® silicon carbide, of dark gray or gray-green color, formed at high temperature on the graphite, to protect it and increase its resistance to erosion and oxidation. The coating varies between .002″ and .030″ but is usually around .010″. It reacts integrally with, and becomes a part of, the graphite surface. A considerable part of the coating, therefore, is chemically derived from the graphite itself. ROKIDE "C" coating has excellent thermal shock resistance and extreme resistance to abrasion. It is slightly permeable. This coating process is covered by U. S. Pat. #2,667,627.

CRYSTOLON® "N"
Silicon Carbide Products

These are monolithic bodies, kiln-fired at high temperature and molded to close dimensions in a wide variety of shapes and sizes. They have greater resistance to mechanical and thermal shock than most ceramics and, compared to other commercial refractory products, are very strong. CRYSTOLON "N" material is dense and extremely refractory. Products made of it have been used successfully at estimated temperatures as high as 5000°F for varying periods of time.

Applications

Typical applications for which these products have shown exceptional promise:

Rockets: nozzles, motor tube linings, thermal barriers.

Guided Missiles: vanes, skin protection, motor components.

Ram Jets: tail pipe lining.

Gas Turbines: inner combustion chamber lining, cross fire tube lining, flap nozzle coating, housing and shroud ring insulation.

Miscellaneous: burner parts protection, electrical insulation, thermocouple tube protection.

Licensing Policy

A license for the use of the ROKIDE "A" aluminum oxide coating process can be obtained from Norton Company.

Other Norton Products

of interest to designers and builders of reaction motors include refractory ceramic materials of commercial type, including fused stabilized zirconia, various CRYSTOLON products, MAGNORITE® fused magnesium oxide products and ALUNDUM® fused aluminum oxide products. Norton also makes a number of refractory carbides, borides and nitrides. These high-melting materials, which have varied applications in many fields, are also the basic ingredients of the famous Norton Refractory ℞'s — refractories *engineered and prescribed* for the widest range of uses.

For further information on Norton products for reaction motors — or for other applications — write, mentioning your requirements, to NORTON COMPANY, 547 New Bond Street, Worcester 6, Mass.

In Rockets, Jet Planes and Guided Missiles, Norton products for reaction motors — ROKIDE "A" Aluminum Oxide Coating, ROKIDE "C" Silicon Carbide Coating and CRYSTOLON "N" Silicon Carbide Monolithic Bodies — are used for many applications.

NORTON
REFRACTORIES
Engineered . . . ℞ . . . Prescribed

Making better products . . . to make your products better

*Trade-Mark

THE CHALLENGE OF CYANOETHYLATION

$$R{\cdot}OH + CH_2CHCN \rightarrow ROCH_2CH_2CN$$

ACRYLONITRILE has thrown laboratory doors wide open to unexplored frontiers. Scores of new compounds are waiting to be born.

By reacting with virtually any material containing a labile hydrogen atom, acrylonitrile presents an exciting challenge to chemists everywhere.

When cotton is reacted with acrylonitrile to replace all or part of the original hydroxyl hydrogen with the group $-CH_2CH_2CN$, a cyanoethylated cotton is produced that is resistant to rot, mildew and heat degradation, and that has improved dyability.

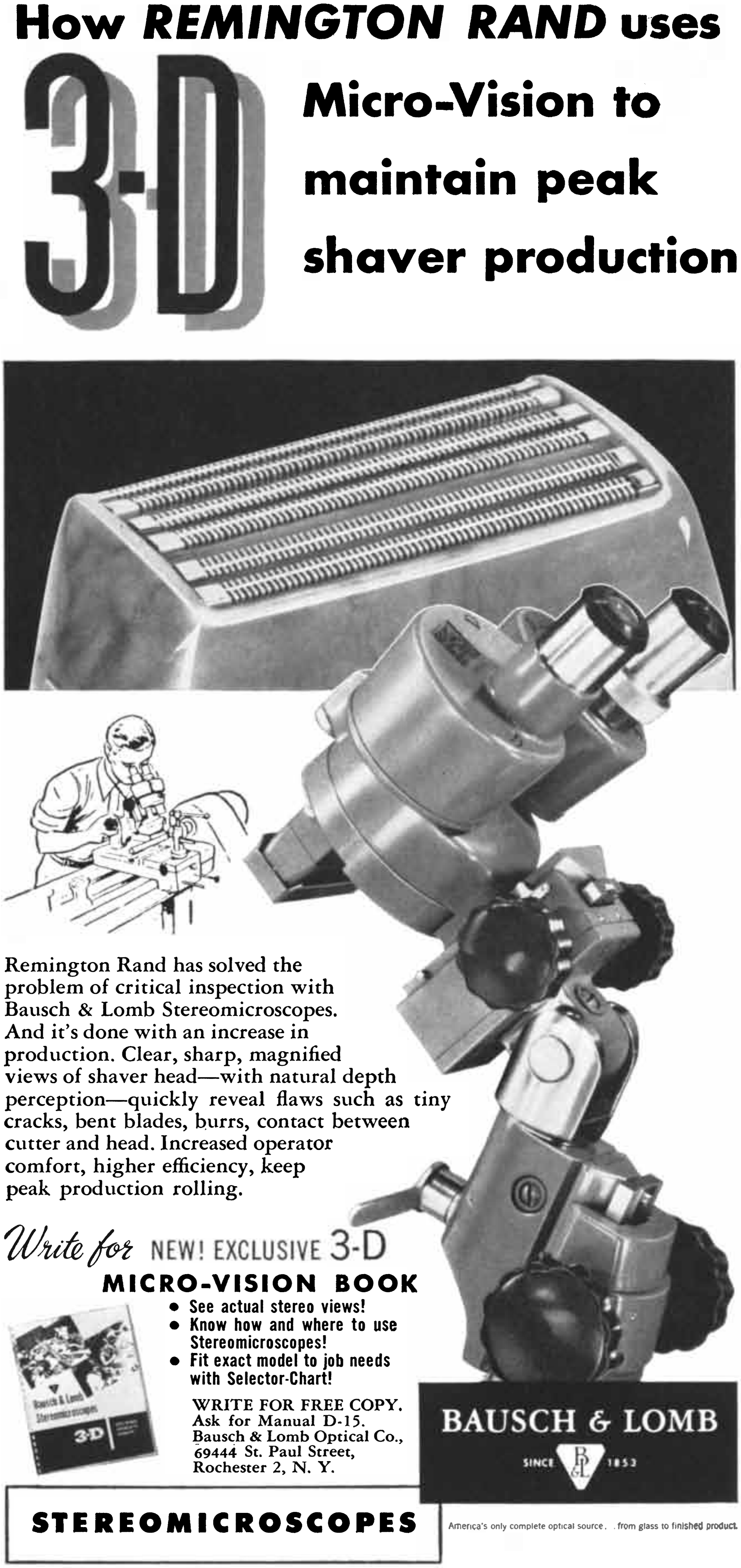
What effects will cyanoethylation produce on other forms of cellulose? Sawdust? Sisal? Paper? Jute? Hemp?

The answers to these questions are still to be written.

Laboratory-size Samples: *If your company would like to experiment with acrylonitrile, you are invited to write Monsanto, the Monomer Headquarters of America for laboratory-size samples. Address your request to Monsanto Chemical Company, Plastics Division, Dept. SA8, Springfield 2, Massachusetts.*

MONSANTO

SERVING INDUSTRY...WHICH SERVES MANKIND



LETTERS

Sirs:

As a neighbor and former colleague of Frits W. Went at the Kerckhoff Laboratories of the California Institute of Technology, I cannot resist adding a bit to the discussion in the June letters to *Scientific American.*

Specifically I wish to take to task Paul A. Fryxell's insistence on separating man from other forms. Each species is of course unique in some respect, but the separation of human peculiarities from those of other organisms should not be done with any particular deference to man. Human characteristics of a societal nature should not be exempted from inclusion among results of natural selection; hence birth control, if it is successful and ultimately a common practice of the human species, will be as "natural" a phenomenon as that control of germination described by Went. One may, I feel, justly deplore the distinction which terms one thing natural selection and another artificial (*i.e.*, human) selection. Further, is there any reason for denying such things as cities, radio programs, and space suits a proper place among the evolutionary adaptations of terrestrial life? Indeed, the elimination of bacterial parasites, or even a Wellesian invader from Mars would have to be classified by

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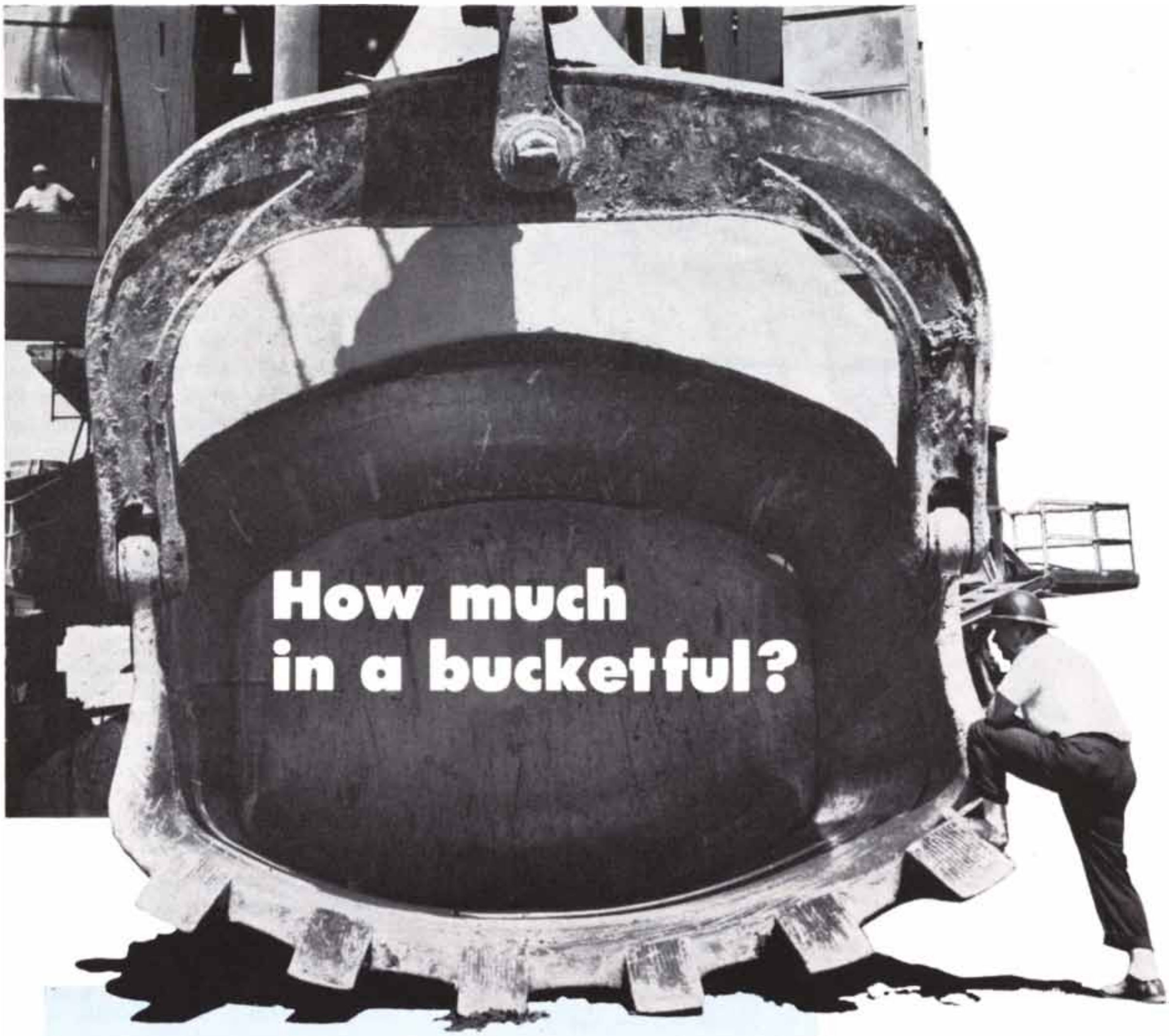


It used to hold 40 cu. yds. Now it holds 50 cu. yds. What makes the difference? Just the type of steel used to make the bucket.

Castings were used formerly—big, bulky castings. They added a lot of dead weight, but they were needed for durability.

Then along came USS "T-1" Steel. Out went castings.

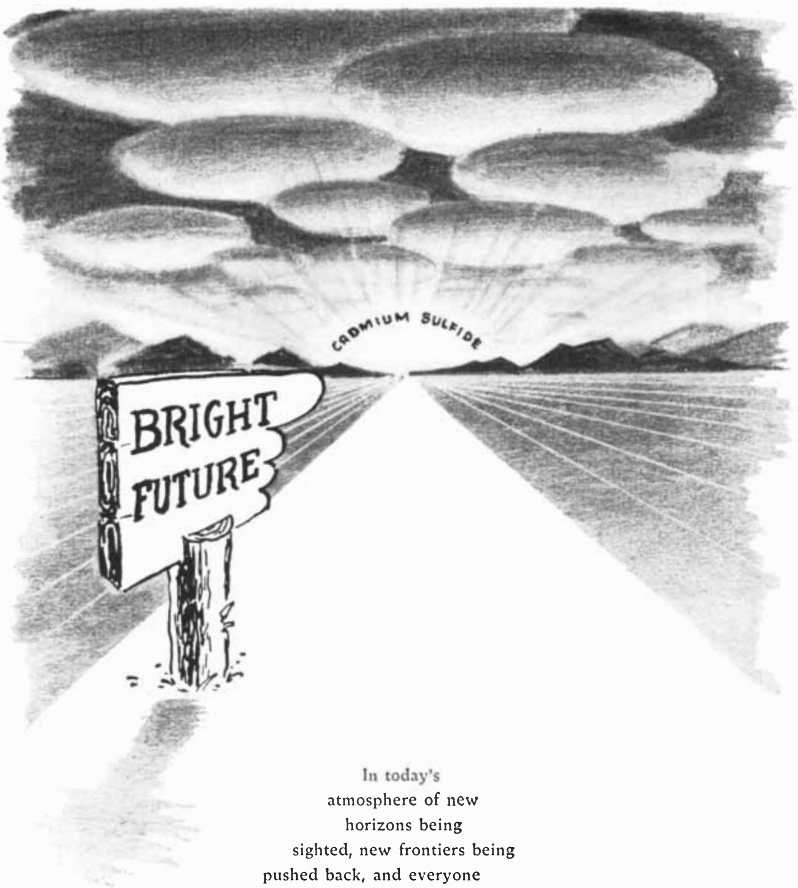
Durability went up, because USS "T-1" is stronger and more resistant to abrasion. **Bucket capacity went up** because USS "T-1" can be used in thinner sections.

Costs went down. Because USS "T-1" is easy to fabricate and requires less frequent maintenance and repair.

USS "T-1" Steel is making possible similar improvements in a great variety of industrial equipment. Its high-temperature strength is being used in steel mill equipment that must operate at temperatures as high as 600° F. Its amazing low-temperature toughness is being used in construction and mining equipment that must withstand severe impact at 40° below zero F. Its high yield strength (90,000 psi. minimum) is being used to reduce the wall thickness, increase the capacity, and cut the cost of pressure vessels, air flasks, and excavating equipment. Its easy weldability—without pre- or post-heating—materially reduces the cost of fabricating heavy-duty, high-strength parts.

More and more engineers are becoming familiar with USS "T-1" steel's amazing capabilities . . . and are daily using "T-1" to improve performance and cut costs. You may be one of those who can use it to advantage. Write for complete information to United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

UNITED STATES STEEL



scientists as a perfectly "natural" event.

By the way, in the matter of warfare, aren't the ants one up on us?

S. M. Siegel

Department of Biology
University of Tampa
Tampa, Fla.

Sirs:

In regard to the fascinating account by Frits W. Went of population limitation among desert plants, it does seem to be a rather broad jump from the lives and ways of desert spermatophytes to the ways of man. The plants do seem to be more sensible in lessening competition by limitation of population than man. However, we are vertebrate animals and as such were derived from lines of evolutionary descent very different from those of the plants.

Still, there are somewhat similar mechanisms among vertebrates which might be much more meaningful as object lessons to man. The lower vertebrates are noted for very high reproductive potentials and very little care of eggs or young by either parent. With the development of the higher vertebrates a very obvious decrease in the annual production of young occurs, accompanied by ever-increasing care of young by the parents, especially the mother. It seems true that with the evolution of parental care large numbers of young were no longer needed, or had little survival value. Of seemingly far greater survival value was the production of fewer offspring and better care of these few. This seems to have been a strong evolutionary trend among the higher vertebrates and without too great difficulty this trend could be interpreted as a lesson of great moral value for man in civilization: produce fewer but take better care of them. Here we are dealing with modern representatives of animals in many ways very similar to those which were our ancestors, not with plants of a very different line of descent.

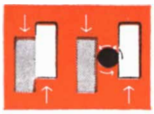
A related but somewhat different aspect of population limitation also becomes apparent in studies made of territorialistic behavior of higher animals. In general mated pairs select and guard an area of the environment suitable and adequate for nesting and rearing of young and will not mate outside this territory. Thus the size of a population of a species tends to be directly controlled by the size of suitable environment (including food supply) for that species. Members of the species which are un-

Here's a

NEW, FAR BETTER ACTUATION METHOD!

Saginaw ball/bearing Screws assure precision positioning with minimum power, size and cost

WHAT IT IS AND HOW IT WORKS



Let's start at the beginning, with the familiar principle that there's far less friction in *rolling* than in *sliding*. By applying this principle,

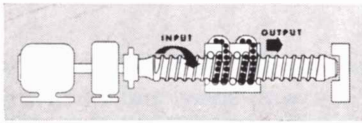
the *Safety ball/bearing Screw* radically increases the efficiency of rotary-to-linear motion (and vice versa). Instead of *sliding*, mating surfaces *glide* on rolling steel balls.

Like stripes on a barber pole, the balls travel toward end of nut through spiral "tunnel" formed by concave threads in both screw and mating nut.

At end of trip, one or more tubular guides lead balls diagonally back across outside of nut to starting point, forming closed circuit through which balls recirculate.

TREMENDOUS ADVANTAGES FOR MACHINE DESIGNERS

Conventional Acme screw's efficiency is less than 25%; *Safety ball/bearing Screw's* ranges from 90 to 95%! Combined with electric, hydraulic or pneumatic power source, it forms an actuator with unprecedented capabilities, that:



SAVES POWER—*Safety b/b Screw* requires only 1/3 as much torque for same lineal output as conventional Acme screw. With far lower static break-away, it operates with much less starting and driving power. This permits the use of much smaller motors with less load on the electrical system.

SAVES SPACE—Permits use of smaller motors and gear boxes; eliminates pumps, accumulators, piping, etc.

ASSURES POSITIVE POSITIONING—permits precision control within thousandths of an inch, plus perfect synchronization.

INCREASES DEPENDABILITY—offers longer life and added security of *exclusive multiple circuits*, plus greatly decreased dirt sensitivity of special "Gothic arch"-shaped races.

REDUCES PART AND INSTALLATION COSTS—savings in weight, motor size, power and auxiliary equipment cut cost, too.

UNITS HAVE BEEN BUILT FROM 1½ INCHES TO 39½ FEET LONG

Every *Safety b/b Screw* is individually engineered for its particular application. Our engineers are eager to help solve your actuator problems *now.*

MAIL COUPON TODAY FOR YOUR ENGINEERING DATA BOOK

(or see our section in Sweet's Product Design File)

Saginaw Steering Gear Div.
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Please send your Engineering Data Book to:

Name—Title..............................
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Safety ball/bearing Screw by Saginaw

able to select and hold suitable territories become nonreproductive drifters, thus limiting population size. This does not mean absence of competition between members of these species. They do compete for territories but at least in most cases the competition seems to be mild with little or no damage done to the competitors. Also there must be more young produced each year than can find suitable territories during the following breeding season, so that the population may be kept up in the face of disease, predation and accidental death. However, the populations of such species cannot explode in geometric progression. They are self-limiting since oversaturation of the environment produces a nonbreeding segment of the population.

Perhaps it would be unwise to draw any moral lesson from this bit of natural history other than to state that it would seem wise to be as sensible as animals and not produce offspring until we are reasonably sure that there is a suitable section of human environment to rear them in. Certain humans do so but others very obviously do not.

F. J. TREMBLEY

Department of Biology
Lehigh University
Bethlehem, Pa.

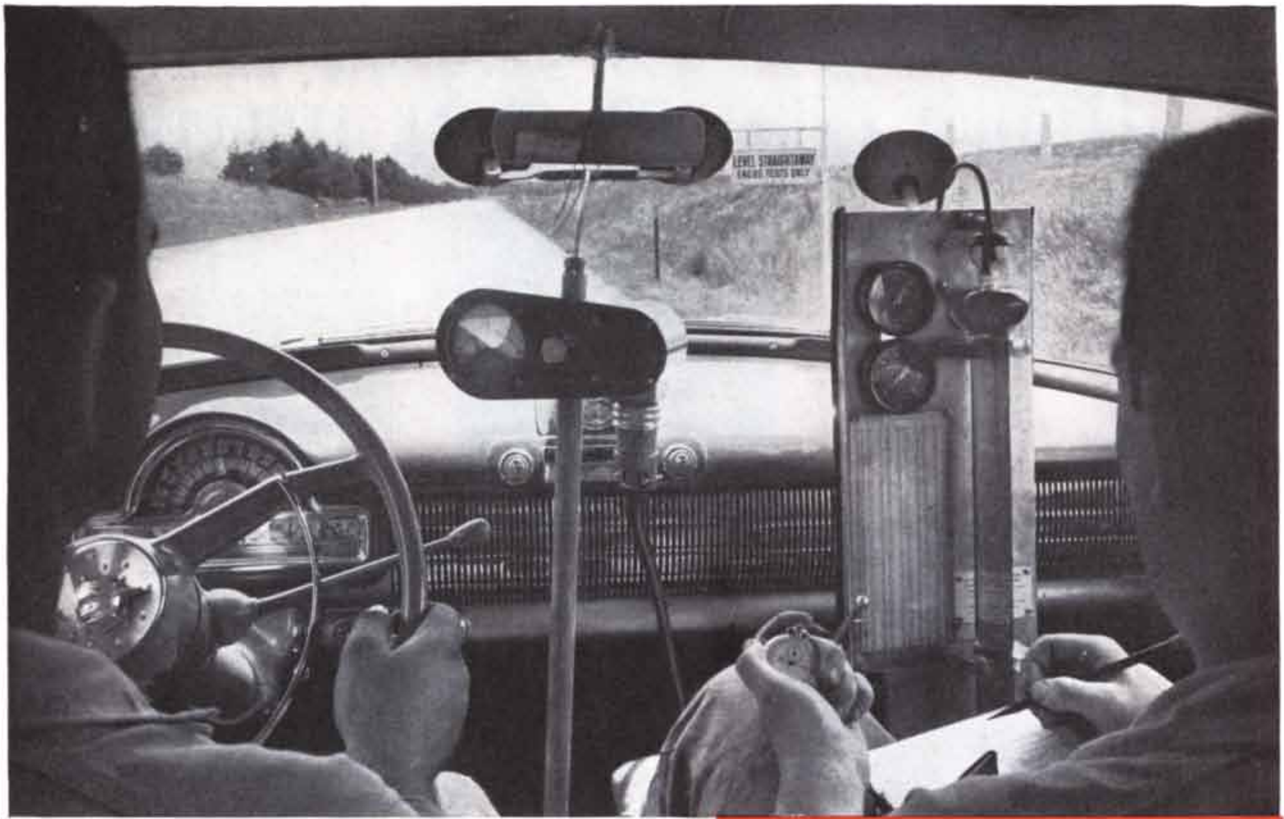
Sirs:

You can figure out the value of pi by dropping a needle on a field of parallel lines *if* you know how to drop the needle to give you what you want ["The Monte Carlo Method," by Daniel D. McCracken; SCIENTIFIC AMERICAN, May]. It is not enough just to be ignorant of how you are dropping it. Nearly 50 years ago my college roommate and I tried to get pi by this method. Pi started low, worked up to 2.5, then to 2.8, then dropped again, moved up, stayed below 3.0. So we decided we were biased. We got a spirit level to make the board horizontal. We got a thistle tube, made it vertical, dropped the needle through it. But there we stuck. Should we aim the tube at a line or in between? Every fixed position has its bias. How does Daniel D. McCracken guarantee that he has the right conditions to produce a chance distribution? What are the conditions for chance? Surely not just ignorance of what conditions apply!

EDWIN G. BORING

Harvard University
Cambridge, Mass.

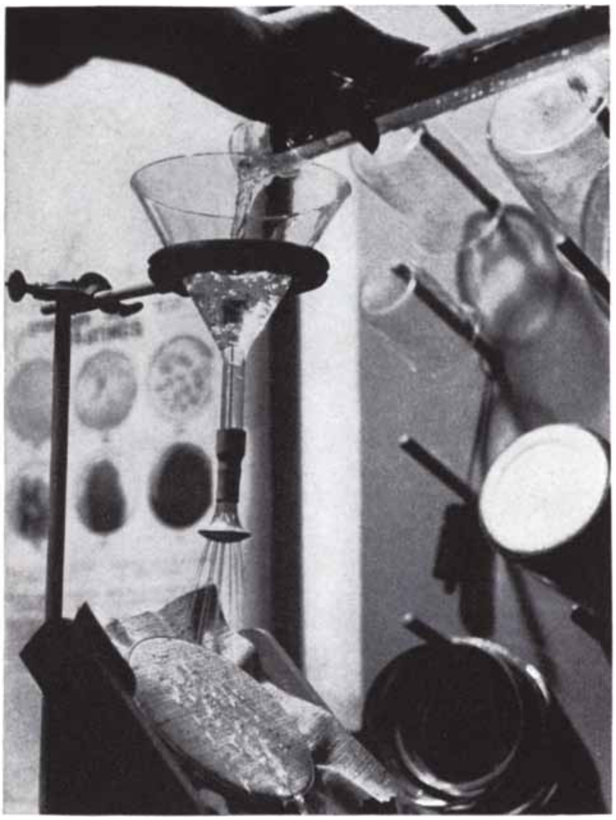
Life... on the Chemical Newsfront



TESTING FUEL ECONOMY of new automobiles is part of Detroit's continuing research to get more power out of gasoline. Burette at right measures fuel consumption. Cyanamid is helping refiners meet the trend toward premium gasoline with a new catalyst—AEROCAT TRIPLE A* High Alumina Catalyst. It is the first catalyst with high alumina content (25%) to prove successful in full-scale commercial use. Offering higher activity and improved selectivity, AEROCAT TRIPLE A Catalyst boosts the efficiency of cracking units. It makes possible greater output of gasoline per ton of catalyst used or better cracking performance at the same rate of catalyst usage. (Industrial Chemicals Division)

NOW AVAILABLE IN SOLID FORM, CYANAMER® 370 Acrylic Polymer is water soluble and has unique properties. It is economical in handling and shipping, and has excellent storage stability. CYANAMER 370 is substantially free of extraneous inorganic salts and has no odor of ammonia in solid form or aqueous solutions. CYANAMER 370 is an extremely uniform product which provides excellent thickening action in emulsions and rubber latexes, strong adhesive and binding properties, and will form films from water solution. Solutions are stable over wide pH range and may be coagulated at pH below 3-4. (Industrial Chemicals Div.)

EFFICIENT PROTECTION FOR VINYL PLASTICS against discoloration and degradation by the ultraviolet component of sunshine now can be obtained with CYANAMID's U.V. ABSORBERS. These compounds are substituted benzophenones and they protect by converting destructive ultraviolet into harmless heat. CYANAMID's U.V. ABSORBERS impart longer life and greater utility to a wide range of vinyl plastics and coating materials. **(New Products Dept.)**



UNIFORM PERFORMANCE THROUGH QUALITY CONTROL is an important feature of CYANA® Textile Finishes. A durable finish such as CYANA PERMEL PLUS® imparts water repellency, spot and stain resistance, and wrinkle resistance to cotton, acetate, nylon, rayon, and blends. In addition, garments made from fabrics treated with PERMEL PLUS Finish not only retain their smart appearance but also wear longer. **(Organic Chemicals Division)**

News Briefs

CALCOFLUOR* WHITE RWS, NEW WATER-SOLUBLE WHITENER, has been developed to facilitate application to textiles made of wool, nylon, acetate, pure silk, and Orlon† acrylic fiber. Now, white and colored garments made from these treated textiles will be whiter and brighter than those made from untreated textiles. **(Organic Chemicals Division)**

SURGILOPE* STERILE PACK is a new and important advancement in packaging sterile sutures for medical use. Developed by Davis & Geck, Inc., a Cyanamid subsidiary, SURGILOPE provides a double envelope of metal foil and glassine to replace glass tube packaging. It is safer to handle, saves time in opening, and requires one third less storage space. At present, SURGILOPE is available only with ANACAP® black silk sutures. However, other sutures will be included as soon as production facilities permit. Samples will be sent to hospitals on request. **(Davis & Geck, Inc.)**

FOR PROMPT RELIEF OF PAIN from peptic ulcers, physicians can now prescribe PATHILON® Iodide Tridihexethyl Iodide. Developed by Lederle Laboratories Division of Cyanamid, this remarkable drug relieves gastrointestinal spasms by blocking the nerve impulses which control the smooth muscle lining of the stomach and intestines. **(Lederle Laboratories Division)**

†Du Pont trade-mark **Trade-mark*

S. A.

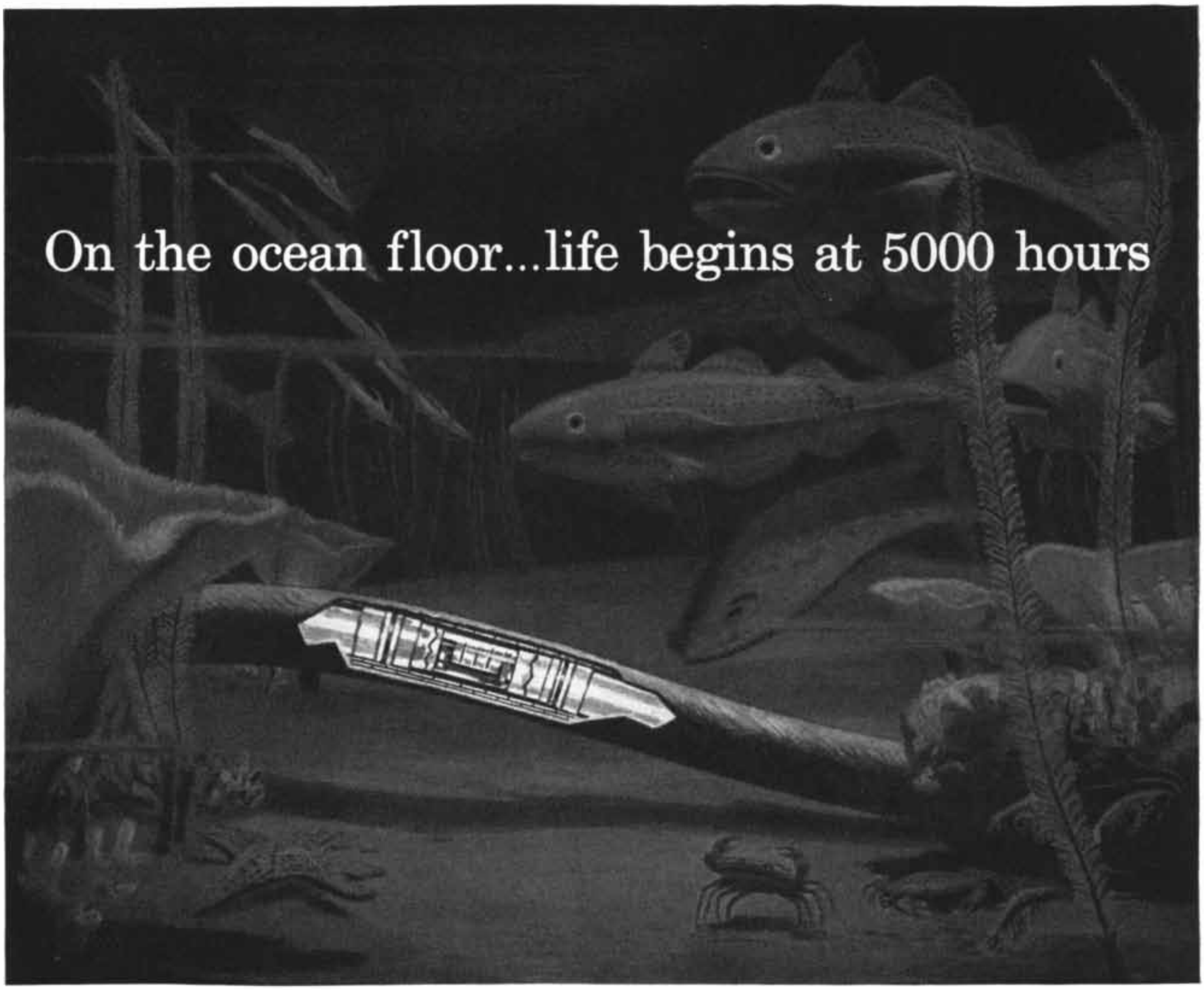
Additional information may be obtained regarding these products by writing on your business letterhead to the Division of American Cyanamid Company, 30 Rockefeller Plaza, New York 20, N. Y., indicated in the captions.

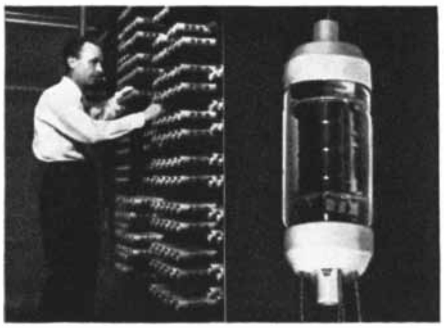
50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

AUGUST, 1905: "The question as to whether or not the earth carries the ether near it in its journey through space is one of very great theoretical importance, and the last word upon it has not yet been said. The results of Michelson and Morley's experiments with their interferometer can be accounted for most simply by supposing that both the earth and the ether near it are moving with the same speed—that is to say, that the earth drags the surrounding ether with it in much the same way as that by which a layer of air is carried by a projectile. Morley has recently varied his previous investigation with the object of testing whether the compensation which cancels the effect due to relative motion is complete in every case. It is the shrinkage of the base-plate of his apparatus which may come into play; and, besides improving the apparatus by increasing its sensitivity, he has changed the material of this plate from iron to wood. There is still absence of any indication of relative motion of earth and ether, and the proportional shortening must therefore be the same as in the previous experiments. It may at first sight seem unlikely that two such different materials should be equally affected. This must be determined by something more fine-grained than molecules, and this something must be essentially identical in both these bodies."

"The decade from 1880 to 1890 may be called the golden age of aetiology, for in these years were discovered the hitherto unknown parasitic microbes of typhoid fever, tuberculosis, malaria, Asiatic cholera, diphtheria, and tetanus. The last decade of a century, which has well been called 'the wonderful,' witnessed the discovery of antitoxins by Emil Von Behring and the beginnings of serum therapy. With the single exception of the changes effected by the acceptance of the theory of organic evolution, there has been no modification of human opinion within the 19th century more wonderful, or more profoundly af-





Electron tubes (right) for the Transatlantic Telephone Cable between Newfoundland and the British Isles are being handmade at Bell Laboratories. Life test bank is shown left. The cable system, which can carry 36 simultaneous conversations, is a joint enterprise of the American Telephone and Telegraph Company, the British Post Office and the Canadian Overseas Telecommunications Corporation.

When the world's first transoceanic telephone cable is laid across the Atlantic it will contain hundreds of electron tubes needed to amplify voices. Deep on the ocean floor these tubes must keep on working, year after year, far beyond reach of ordinary repair services.

Bell Telephone Laboratories scientists have developed a tube of unique endurance. Before a tube is even considered for use in the cable it is operated for 5000 hours under full voltage—more than the entire life of many tubes.

But survival alone is not enough. During the test each tube is exhaustively studied for behavior that may foreshadow trouble years later. Tubes that show even a hint of weakness are discarded. For the good ones, a life of many years can be safely predicted.

Bell Telephone Laboratories scientists began their quest for this ocean-floor tube many years ago. Now it is ready—another example of the foresightedness in research that helps keep the Bell Telephone System the world's best.

BELL TELEPHONE LABORATORIES

Improving telephone service for America provides careers for creative men in scientific and technical fields fecting the general conduct of human life, than that in our attitude toward the nature, the causation and the prevention of disease—that is to say, toward public health science."

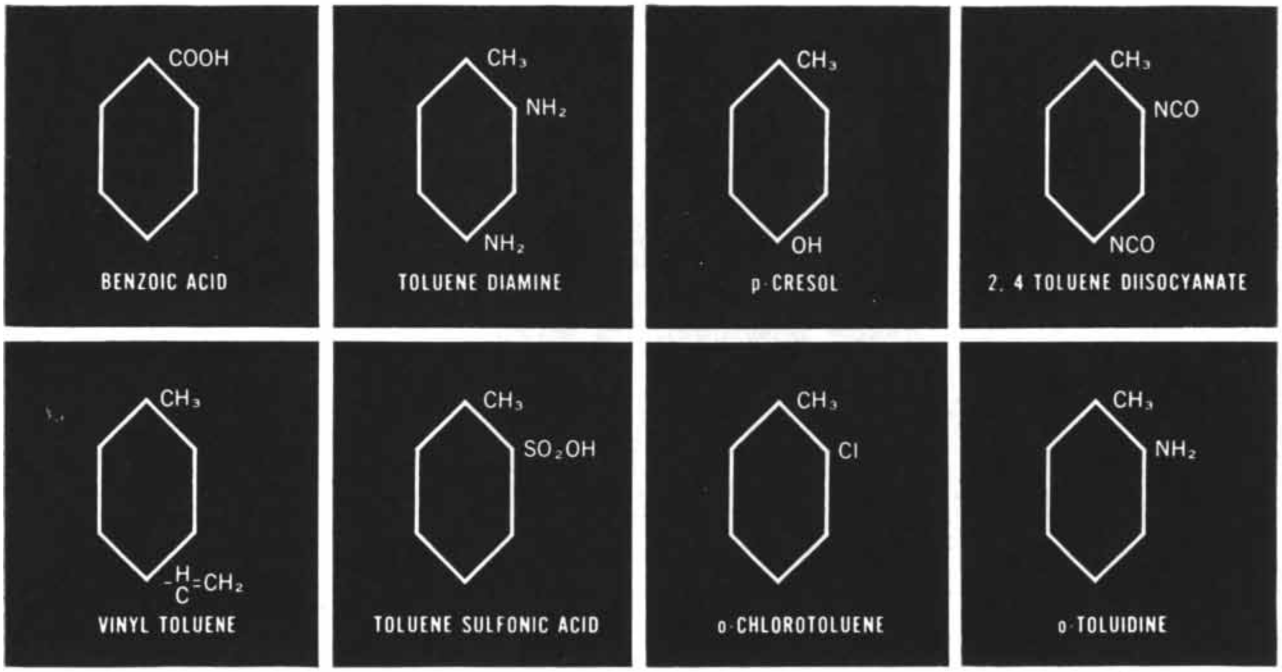
"For a long time it has been the object of the Flagstaff Observatory, of which Prof. Percival Lowell is the head, to photograph the enigmatic canals of Mars. Mr. Lampland, of that observatory, has at last succeeded in accomplishing the difficult task. Prof. Lowell determined that the attempt should be made with a bioscope film, in which many successive pictures may be taken, in the hope of securing among them one which would show the canals. A chronophotographic apparatus was therefore devised. Inasmuch as such fine details as the canals, owing to the air-waves, play bo-peep with either observer or camera, it is not to be expected that the more delicate of them should appear in every print. Yet they turn out to come nearer to doing so than could have been anticipated."

"The following cablegram from Commander R. E. Peary was received by the Arctic Club: 'Domino Run, Labrador, July 29, 1905. Arrived this evening. Cross to the Greenland coast from here. All well. Peary.' This indicates that the *Roosevelt* and the *Erik* have made a record run from Sidney, where they were reported July 26, three days before the date of this dispatch, and unless unexpected obstacles were met in Melville Bay the expedition is now at Etah, Greenland, or Cape Sabine, Grinnell Land."

SCIENTIFIC AMERICAN

AUGUST, 1855: "There are indications that the seat of the whaling interests is about to be transferred from the Atlantic to the Pacific Coast. Arrangements are already in progress with several houses to transfer their business from New Bedford and other places to some point on the Pacific Coast. San Francisco, Benicia, Oakland, and Monterey are spoken of. Orders have been given to captains of vessels now employed in the whale fisheries in the North Pacific to recruit their men at the ports of California."

"Our Paris correspondent reports that a new metal lately discovered there is attracting considerable attention. From



If you produce these or related compounds . . .

SUN TOLUENE WILL GIVE YOU HIGHER YIELDS . . . MINIMUM IMPURITIES

The increased use of toluene as a chemical raw material created the demand for a purer product. Sun met this demand last year when it built its new aromatics plant.

Since then, industries using new high purity Sun Toluene have been reporting increased plant efficiency . . . better quality in their finished products . . . increased life of many of their catalysts.

Sun Toluene has a purity (mol. percent.) of 99.9. The bromine index test, a most sensitive measure of olefins, typically shows negligible results. Typical results from the isatin test show that Sun Toluene is thiophene-free.

In addition, Sun Toluene is guaranteed to contain less than 0.5% paraffins . . . well below the ASTM maximum of 1.5%. *As a matter of fact, by the ASTM Test, Sun Toluene normally contains no paraffins whatsoever.*

TYPICAL TESTS

Paraffins	Nil
Bromine Index (unsaturates)	Negligible
Acid Wash Color, ASTM	1
Distillation Range	0.6 C incl. 110.6 C
Sulphur, Wt. %	0.001
Mol. % Purity	99.9
Thiophene (Isatin)	Negative

For complete specifications and more information about Sun Toluene see your Sun representative . . . or write for Technical Bulletin #27. Address SUN OIL COMPANY, Philadelphia 3, Pa., Dept. SA-8.

INDUSTRIAL PRODUCTS DEPARTMENT

SUN OIL COMPANY

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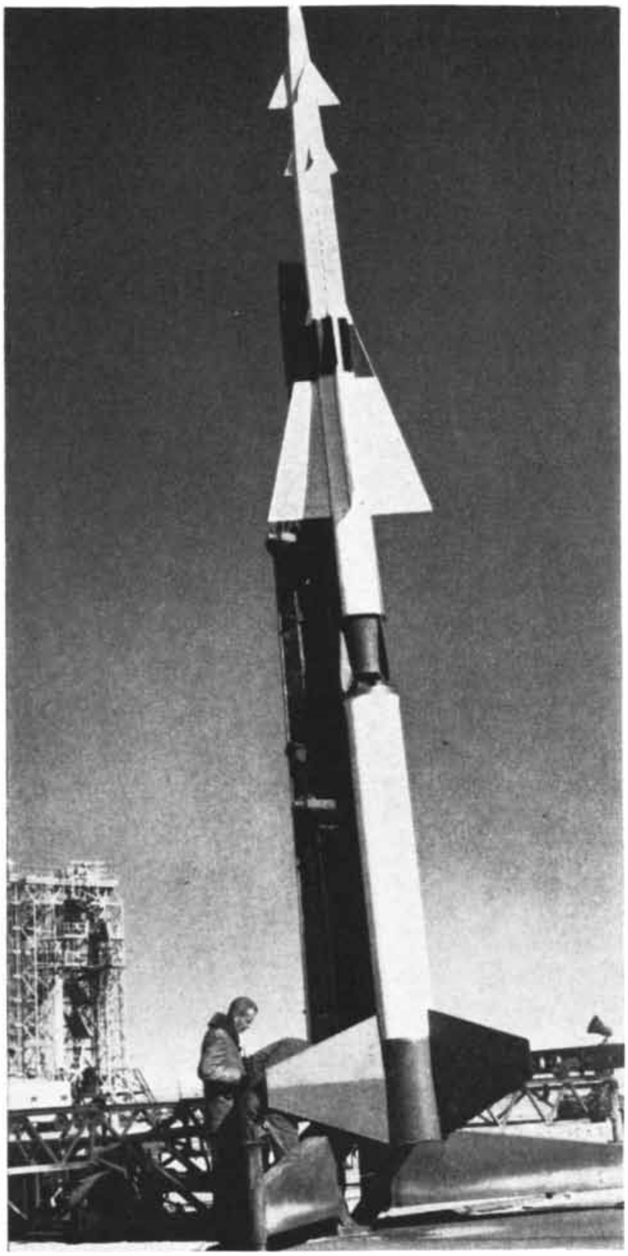
SUNOCO ®

representations made to the Emperor respecting its importance, he granted out of his private purse the sum of $6,000 to the young chemist Deville, the inventor, to assist him in perfecting it. This new metal is called aluminum, and until now it has been obtained with the greatest difficulty. It is obtained by a re-action of sodium on chloride of aluminum. M. Deville has made another discovery that promises well."

"Horace Greeley, Esq., editor of the N. Y. *Tribune*, recently attended a trial of Plows and Mowers on the 7th July last, at Guignen, the 'Imperial' College of Agriculture, some 25 miles west of Paris. He says:—'A great number of Plows were tried here, and that of the Messrs. Howard, from Bedford, England, was pronounced the most effective. There was no Plow entered from our country, but one from Canada was tried and did good work. We all went out in the afternoon to a large clover field, where quite a cluster of the farmers of the vicinage had assembled to witness the operation of Mr. McCormick's Mower. The machine worked admirably, cutting very smoothly, closely and clearly a swath five feet wide as fast as the span of horses drawing it could walk, and evidently making very moderate demands on their muscles."

"The steamship *James Adger* sailed from New York this week for Newfoundland, to assist in laying down the first section of the submarine telegraph which is to connect this country with Europe. A large party of ladies and gentlemen were on board, among whom were Prof. Morse, inventor of the telegraph, Peter Cooper and Cyrus W. Field, Esqrs., prominent projectors of this enterprise, and Lieut. Maury, and Professor Silliman. The duty assigned to this steamer is to take in tow the cable ship *Bryant*, and lead her across that portion of the Gulf of St. Lawrence which exists between Port-aux-Basques, in Newfoundland, and Cape North—above Halifax—a distance of 74 miles. The cable was made in England and has but recently arrived in the *Bryant*. It will be run out from her stern while in tow of the steamer. The cable is composed of three wires, and is only 1½ inches in diameter. Weight of the whole, 400 tuns. When these wires are laid the island of Newfoundland will be connected, telegraphically, with the American continent, and in the course of two years or less, the great inter-oceanic wires will be laid, and all Europe brought into instantaneous communication with this country."



Designing and producing intricate bread-wrapping machinery, or developing guided-missile launching equipment... each demands advanced technology. And these are but two of the *hundreds* of complex tasks the AMF organization performs every day.

The highly specialized yet widely diversified activities of some 35 engineering and production facilities provide AMF with a wealth of experience that covers nearly every field of industry. And it is immediately available to *you*.

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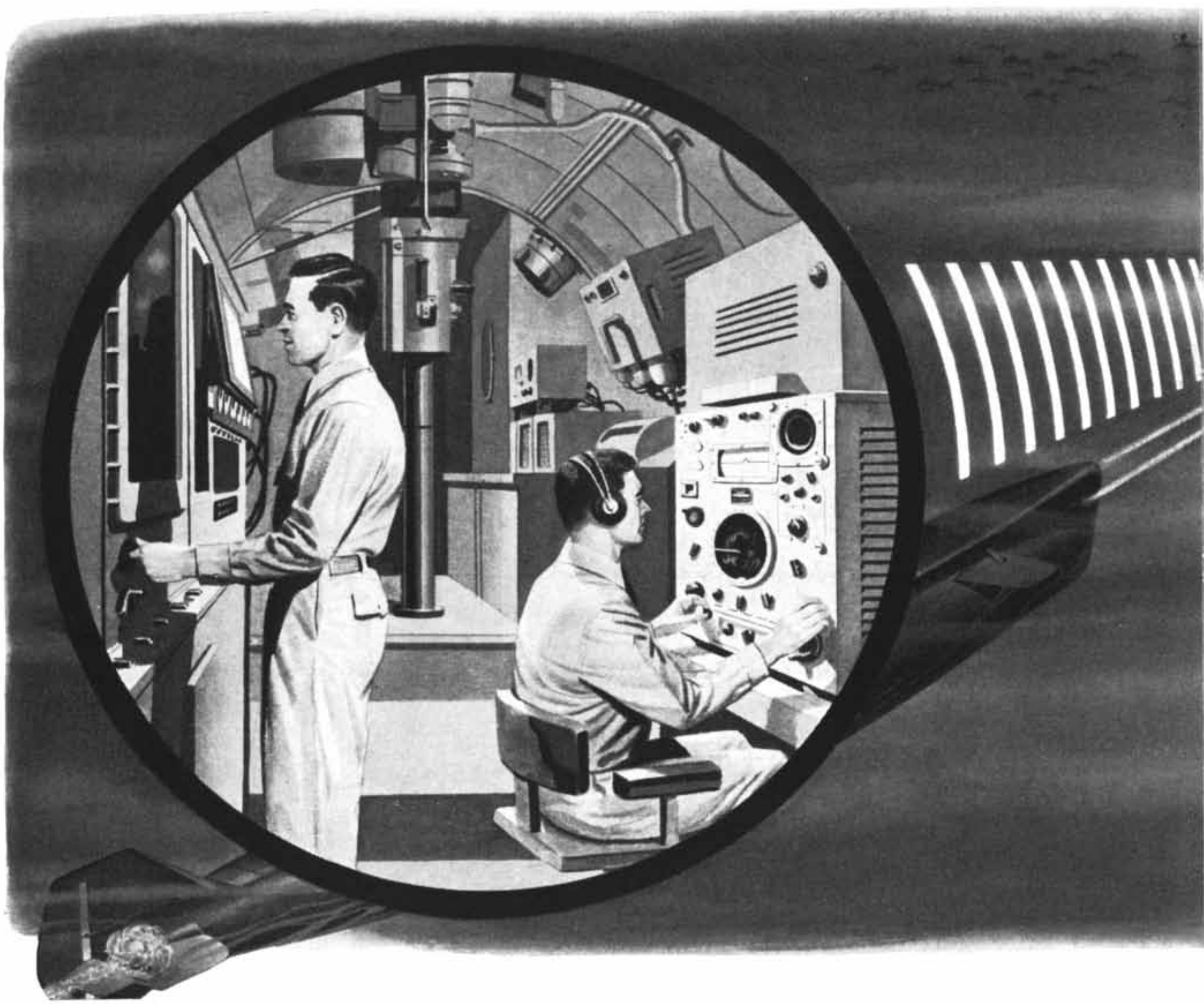

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THE AUTHORS

LAWRENCE P. LESSING ("Automatic Manufacture of Electronic Equipment"), a writer on science and technology, is a frequent contributor to SCIENTIFIC AMERICAN. He was the author of the article on coal in last month's issue.

JACK SCHUBERT ("Radioactive Poisons") is senior chemist in the division of biological and chemical research at the Argonne National Laboratory. A graduate of the University of Chicago, where he obtained his Ph.D. in 1944, he worked during the war at the Metallurgical Laboratory in Chicago and at the Clinton Laboratories in Oak Ridge on the purification and separation of uranium and fission products. His Ph.D. thesis is still classified as secret. In 1945 he joined the Argonne National Laboratory out of "an urge to apply ideas of physical chemistry to problems in biology and medicine." He conceived the idea that radioactive metals in the body could be displaced by nontoxic metals and found that zirconium salts would work. He has also studied poisoning by nonradioactive metals such as beryllium, and with Marcia White Rosenthal has developed a new method for the treatment of metal poisons, involving the use of a dye which reacts with the metal and inactivates it. In 1947 Schubert made a detailed analysis of the aftereffects of fission products released in the 1946 bomb test on Bikini.

JEROME NAMIAS ("Long-Range Weather Forecasting") is chief of the extended forecast section of the U. S. Weather Bureau. He developed his interest in meteorology as a high-school student in Fall River, Mass., when "a stimulating physics teacher brought the subject vividly to my attention. I was soon devouring all the literature on meteorology in the Fall River Public Library, spending my hard-earned cash for barometers, hydrometers and other meteorological instruments and trying to make weather forecasts." After studying at M.I.T. in the early 1930s, he served as a meteorologist with Transcontinental and Western Airlines for a year, then returned to M.I.T. as a research associate. He took his M. S. there in 1941, then went to Washington as chief of the extended forecast section. During World War II he made special forecasts for the U. S. Air Force and Navy. His forecast for the North African invasion won him

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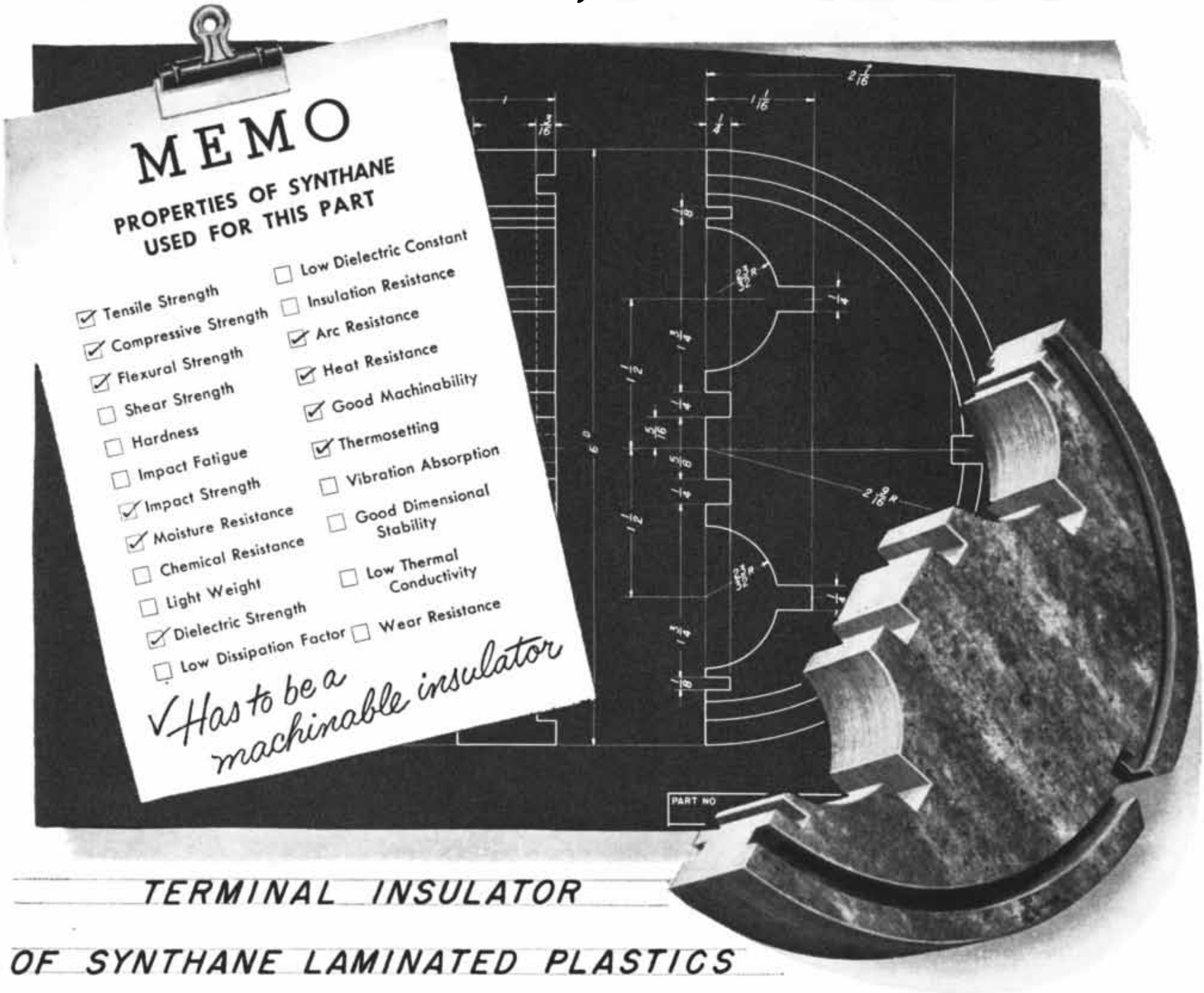

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a citation from the late Secretary of the Navy Frank Knox. This year Namias received a Rockefeller Foundation Public Service Award which will enable him to study in Europe, mainly Stockholm. He plans to work on the use of high-speed computing machines and on extending forecasts to an entire season.

RONALD RIBBANDS ("The Honeybee") is an entomologist at the Rothamsted Experimental Station 25 miles from London. He took a B.A. in 1935 at Downing College, Cambridge, and from 1936 to 1940 was with the zoology department of Glasgow University. During the war he served in the Royal Army Medical Corps, working on malaria control in British West Africa and later in Southeast Asia. Fascinated by the discoveries of Karl von Frisch about bees, Ribbands joined the bee department at Rothamsted in 1947. He is now a principal scientific officer, still carrying out experiments on food sharing and communication among honeybees, but "taking more and more interest in ants and termites and hoping to obtain an opportunity of working on these insects instead, in order to compare their behavior and social life with that of the honeybee." His principal relaxation, he says, is overseas travel: "Would like to come to N. America."

J. H. RUSH ("The Speed of Light") is associate professor of physics at the Texas Technological College in Lubbock. Born in the cotton country of central Texas, he left the farm at the first opportunity. He had experimented with radio and chemistry in a shed, until a bottle of white phosphorus exploded in his hand. He switched to physics and taught himself, no course being offered by his high school. After graduation from high school in 1928 he operated the Dallas police radio. Later he got a B.A. and an M.A. in physics at the University of Texas, taught for three years and wound up in the Clinton Laboratories at Oak Ridge. He considers that his education during a year in Washington in 1946-1947 as treasurer of the Federation of Atomic Scientists "was worth a couple of Ph.D.'s." After this political interlude he got a Ph.D. at Duke University for work in ultraviolet spectroscopy. He helped design the optical system for the six-inch coronagraph at the High Altitude Observatory at Climax, Col.

LOUIS LASAGNA ("Placebos") holds two assistant professorships at The Johns Hopkins University School of Medicine in Baltimore, one in medicine

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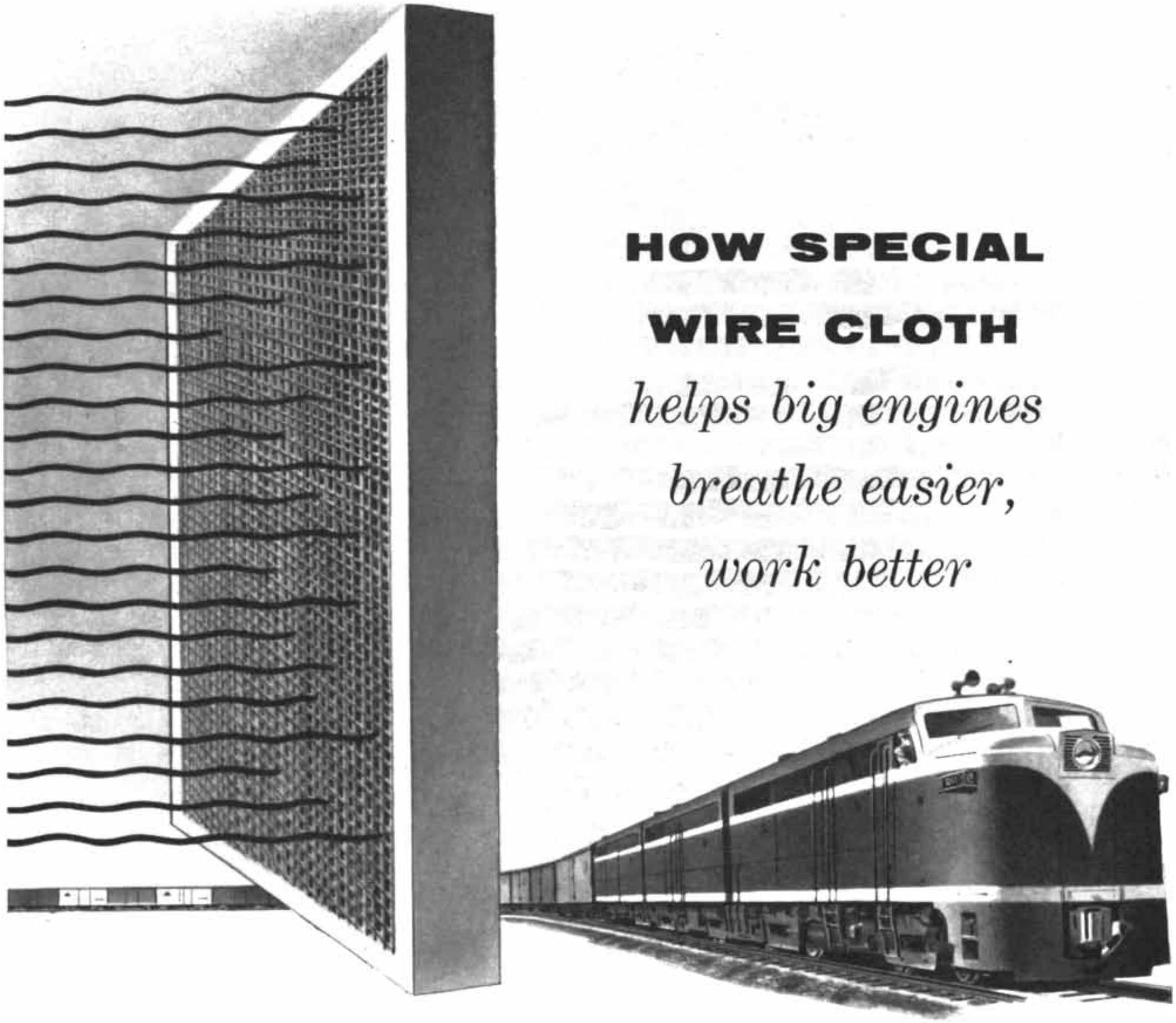

● Keeping harmful grit and dirt out of the lungs of big engines, like locomotive diesels, is no small problem. Determined to do the job better than ever before, a leading filter manufacturer turned to the *Reynolds Wire Division* of National-Standard for a special wire cloth that would trap all the dirt and still let such engines breathe the terrific volume of air they need.

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and one in pharmacology. This bifurcation is in line with his career to date. After taking a B.S. at Rutgers University and his M.D. at the College of Physicians and Surgeons of Columbia University, he trained in internal medicine, but then in 1950 veered off into studying pharmacology at Johns Hopkins and working with Henry K. Beecher at the Massachusetts General Hospital on an investigation of responses to drugs. At Johns Hopkins he is organizing a division of clinical pharmacology within the department of medicine. His research centers on methodology in the clinical trial of drugs and on the influence of nondrug factors.

ARTHUR D. HASLER and JAMES A. LARSEN ("The Homing Salmon") are both at the University of Wisconsin. Hasler is head of Wisconsin's Lake Laboratory and professor of zoology. Born in Utah, he studied in Germany, graduated in 1932 from Brigham Young University, worked for two years as an aquatic biologist for the U. S. Fish and Wildlife Service in Chesapeake Bay and in 1937 took his Ph.D. in zoology at the University of Wisconsin, where he has taught ever since. He spent a couple of summers as director of the Lake Geneva Institute of Natural Science before the war, and in 1945 the War Department sent him to Germany in its Strategic Bombing Survey. Hasler is a former vice president of the Society of Limnology and Oceanography. He is currently in Munich working with Karl von Frisch at the Zoological Institute. Larsen is the science editor of the University of Wisconsin News Service. He has done some research in animal and plant ecology, but his only part in the article here was as a collaborator with Hasler in writing it.

JOTHAM JOHNSON ("The Changing American Language") is chairman of the classics department at the Washington Square College of New York University. A note about him appeared in the May, 1954, issue of this magazine, along with his article on "The Language of Homer's Heroes."

STUART HAMPSHIRE, the reviewer of Ernest Campbell Mossner's *The Life of David Hume* in this issue, teaches philosophy at the University of Oxford. A graduate of Balliol College at Oxford, he was a Fellow of All Souls College before the war, served in the British Army and in the Foreign Office, and returned to Oxford as a Fellow of New College. He was a visiting professor at Columbia University in 1954.

THE COVER

The painting on the cover is a fanciful representation of experiments to determine what sensory apparatus enables a spawning salmon to find its way upstream to the waters of its birth (*see page* 72). The fish in the painting are tiny salmon fingerlings that were used in some of the experiments. In one of these experiments the fingerlings were placed in a tank from which led four runways, each of which was obstructed with a series of small waterfalls. At the upper end of each runway was an apparatus by which odors could be released in the water. When an odor was released in one runway, the experimenters observed the distribution of the fingerlings in all four runways. This and similar experiments strongly suggest that the homing powers of the salmon are due to its sense of smell. The characteristic odor of its natal waters is perhaps due to their unique combination of aquatic plants, some of which are shown at the bottom of the painting. At the top a fingerling is shown ascending a waterfall in the experiment.

THE ILLUSTRATIONS

Cover painting by Gyo

Page	Source
29-33	Paul Weller
34-39	Argonne National Laboratory
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56	John Langley Howard (*top*), Colin G. Butler
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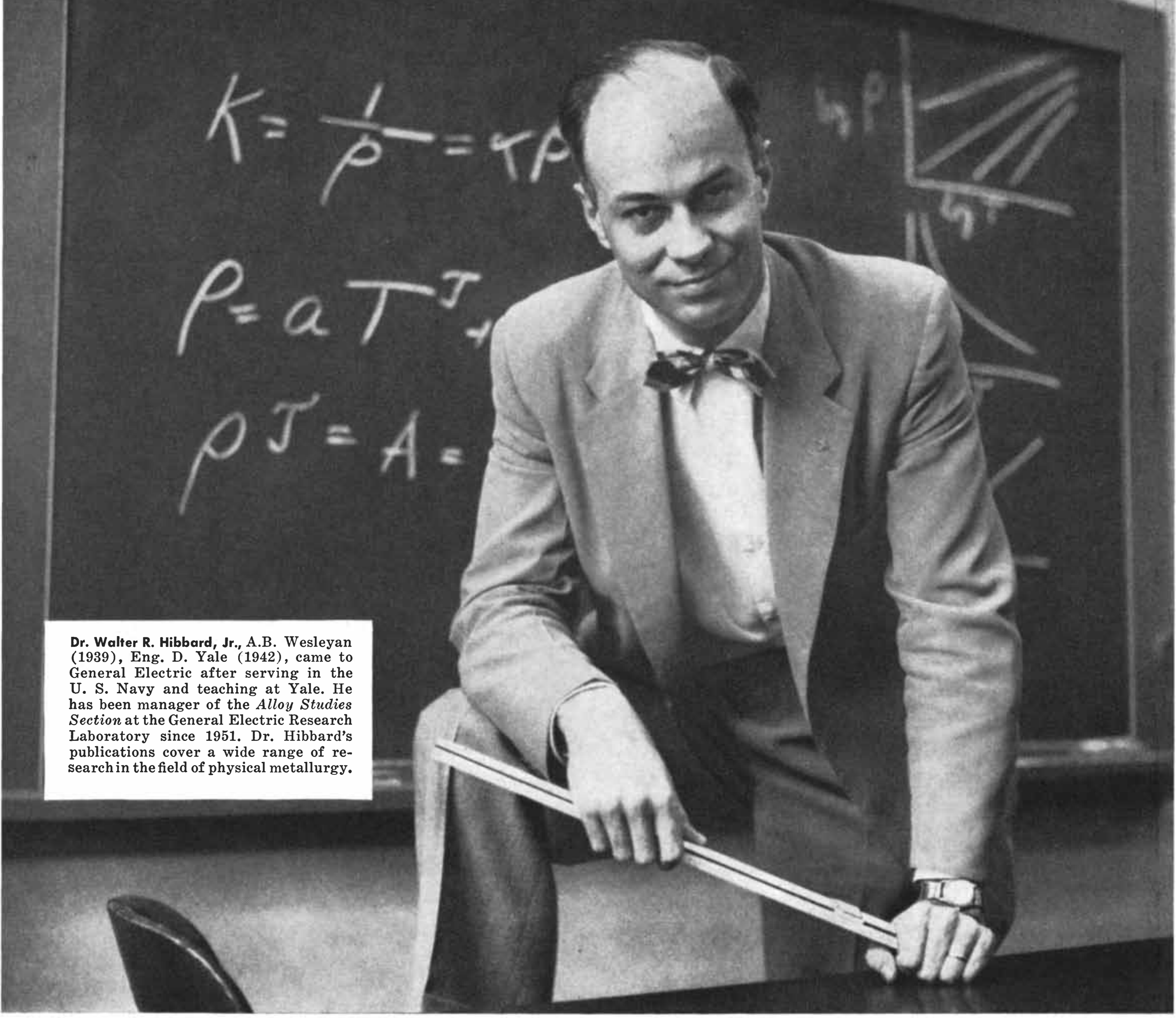

Dr. Walter R. Hibbard, Jr., A.B. Wesleyan (1939), Eng. D. Yale (1942), came to General Electric after serving in the U. S. Navy and teaching at Yale. He has been manager of the *Alloy Studies Section* at the General Electric Research Laboratory since 1951. Dr. Hibbard's publications cover a wide range of research in the field of physical metallurgy.

New alloys for special uses

General Electric's Dr. Walter R. Hibbard, Jr. clarifies relationships between structure and properties

Recently the G-E Research Laboratory was asked to design an alloy to be used in a new type of heating element. In addition to good formability, the alloy had to have a special temperature-resistivity curve not available in any commercial material. Dr. Walter R. Hibbard, Jr., after less than an hour with pencil and paper, came up with the answer — a new composition and detailed processing instructions.

Dr. Hibbard's success was dramatic evidence of how metallurgy has progressed from an industrial art to a science. Until the last few years, new alloys with prescribed physical, electrical or mechanical properties had to be developed primarily by trial-and-error "cookbook" methods. Dr. Hibbard and his associates, through their basic studies of atomic arrangement in metals, are shedding new light on the relationships between the *structure* of alloys and their *properties*. This General Electric research will play an important role in the many areas of our technology where future progress is dependent on improved materials.

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CONTENTS FOR AUGUST, 1955 VOL. 193, NO. 2

ARTICLES

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AUGUST, 1955 VOL. 193, NO. 2

Automatic Manufacture of Electronic Equipment

"Modular design" of the parts of electronic circuits transforms the traditional hand-assembled maze into an orderly collection of uniform elements that can be plugged together automatically

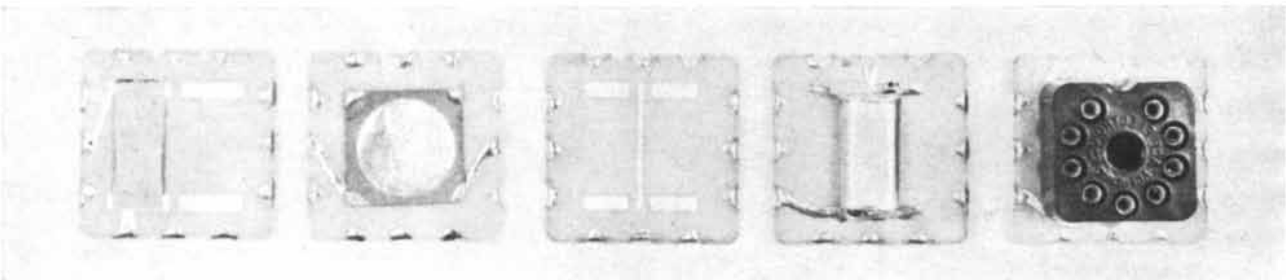
by Lawrence P. Lessing

Two years ago the National Bureau of Standards succeeded in designing a pilot plant, bearing the name Project Tinkertoy, which is perhaps the closest thing to an automatic factory outside the chemical industry. It manufactures circuits and electronic elements. The production system is not fully automatic, but it has mechanized some of the basic stages of parts manufacture and assembly and is one of the first practicable attempts at automation in its field. The Modular Design and Mechanized Production of Electronics, as it is now called, has been adopted by at least one manufacturing firm.

The Bureau of Standards was drawn into the problem in 1950 by the Navy Bureau of Aeronautics. Concerned about the increasing complexity of electronic gear and the time required to manufacture it, the Navy asked the Bureau of Standards to see if it could devise a mechanized production system. Electronic equipment is put together largely by hand. Workers must assemble and solder together a maze of wires, coils, resistors and condensers—a maze known in the trade as "a can of worms," for reasons which are at once clear to anyone who glances into any radio or television chassis.

An earlier attempt had been made to design an automatic system in England. In 1947 an electronics engineer, John A. Sargrove, had built a machine called ECME, for Electronic Circuit Making Equipment, which was a true automaton. With it he proposed to manufacture complete radio circuits of a simple type and more complex electronic equipment. The machine ran into material shortages and internal trouble, however. It was so complex and closely organized that any malfunction in one stage of operations was sufficient to shut down the whole machine. The circuits it manufactured developed electrical breakdowns. When the market for which the simple circuits were intended disappeared (they were to be made for China), the development of ECME was halted.

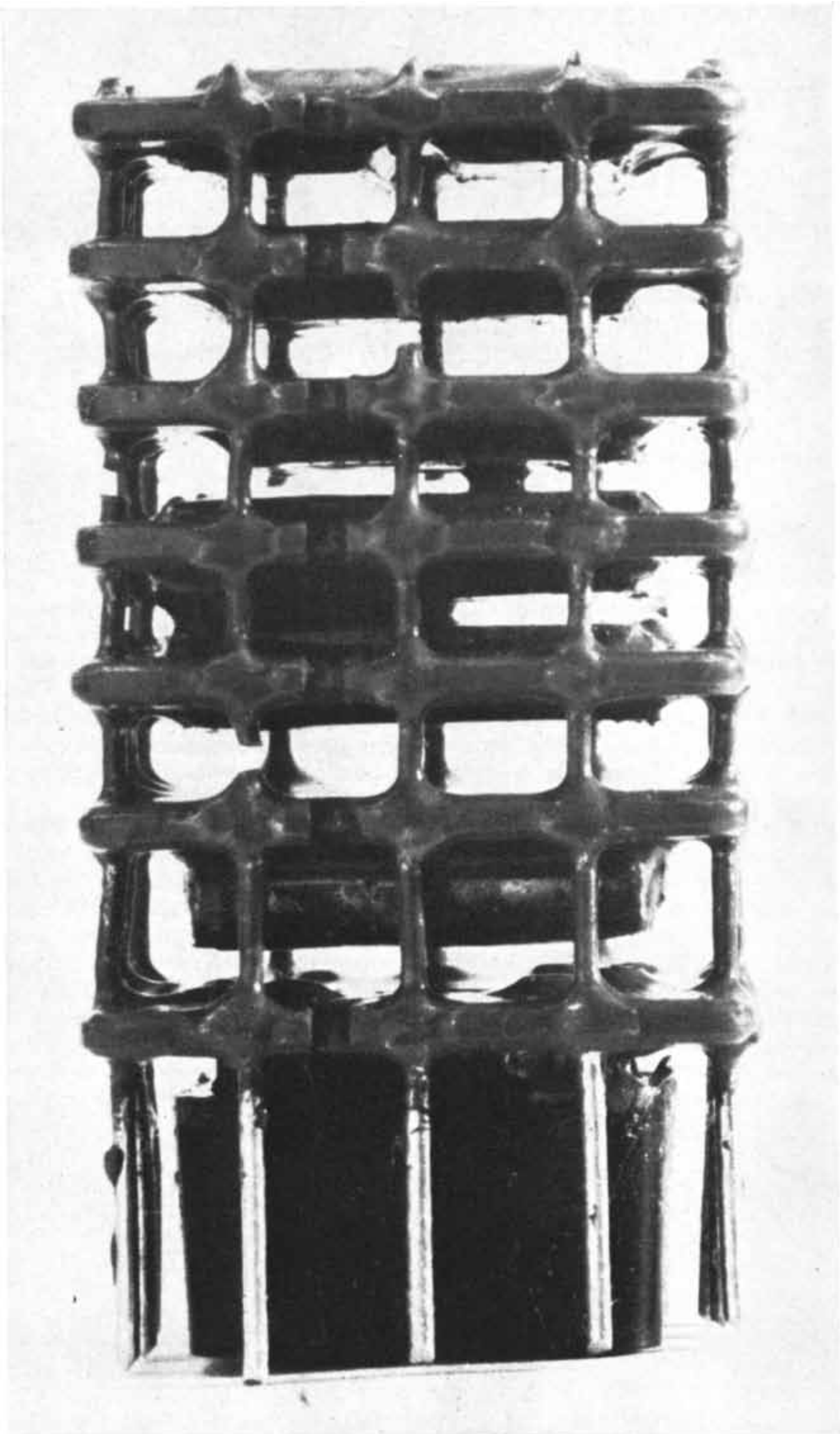
The Bureau of Standards workers, headed by J. Gilman Reid and Robert L. Henry, set a more modest goal. They had had considerable experience in designing printed circuits and miniature electronic components for the proximity fuse, and they undertook an analysis based on their experience. They realized that the major requirement was to mechanize the manufacture of resistors, condensers, inductors and their linkages, which make up some



CERAMIC WAFERS are the fundamental structural units in modular design. Resistor tapes are mounted on the wafer at the left and on the reverse side of the third from left. Second and fourth units carry capacitors. Vacuum tube socket is attached to wafer at right.

60 to 80 per cent of most electronic equipment and are costly to assemble. The problem, then, was to standardize these parts and redesign them for machine production.

Resistors and condensers are the elements that control the voltage and types of current fed to the various electronic tubes in a circuit. A resistor is a wire or other material of low conductivity which has the effect of retarding and diminishing the flow of current. One of the commonest types is a tiny tube of high-resistance carbon with wire leads at both ends. A condenser, also called a capacitor, is a device made of two conducting surfaces or plates separated by an insulator, which causes one of the plates to alternately store and discharge a charge, with the effect of stepping up, smoothing out or otherwise modifying the current. One commonly used capacitor consists of two strips of metal foil separated by a strip of linen paper, the whole rolled into a tube and dipped in wax. An inductor is a tiny coil of wire which transfers current from one stage to another.

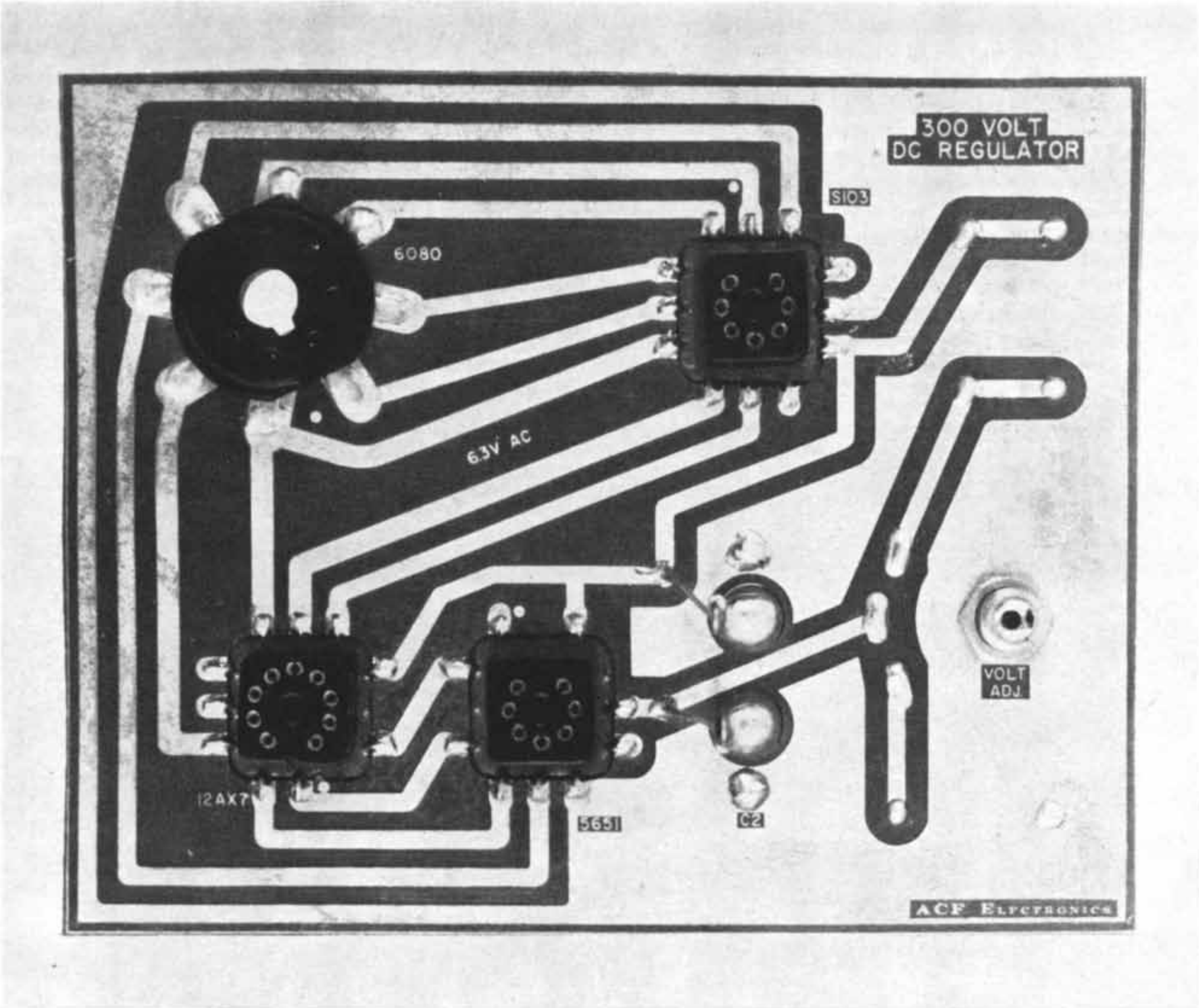


ASSEMBLED MODULE consists of a stack of wafers coated with opaque plastic. Vertical wires through notches in the wafers provide electrical connections between the parts.

Henry, who supervised the development of the modular idea, used printed circuits as the starting point. The printed circuit is a compact device in which the usual wires are replaced by a network of fine lines of silver printed and bonded on a plastic or ceramic surface. Henry's group conceived an ingeniously simple unit, consisting of a thin ceramic wafer with a circuit printed on it and flat resistors, capacitors or other components mounted on the circuit. The wafer itself is about the size of a postage stamp, and it has three small notches along each of its four edges. The notches are for wires to connect the wafers together. A stack of four to six wafers, linked by short lengths of wire soldered into their notches, forms a complete circuit for one electronic tube. Such a unit, a little over an inch high, can consolidate a dozen or more resistors, capacitors and other components and perform all the functions of a conventional circuit stage. The tiny skyscraper units may be put together like building blocks to form an electronic assembly.

The advantage of this modular design is that it breaks down the production units to basic, standard items which can be mass-produced by batteries of machines and then assembled by machine into a variety of different circuits. The module's layer construction, moreover, provides an insulating layer of air to make for better electrical performance. The whole effect of the design is to reduce circuitry to a form as compact, standardized and easily installed as the electronic tubes with which it is associated.

Once the module had been worked out, the next step was to design the machines to handle it. The entire plan of a four-wafer or six-wafer unit is first diagrammed on a master work sheet. It provides the stencil patterns for the printed circuits, indicates the circuit and components to be placed on each wafer, shows how the wafers are to be connected and tells the quantity of each component to be made. It supplies data which, transferred to punch cards, control each step of manufacture down to the final assembly of the module.



VOLTAGE REGULATOR contains three modules (*two at bottom, one at upper right*) and a large tube socket (*upper left*). The light-colored paths are electrical connections printed on the chassis. In assembly, module leads are simply soldered to printed conductors.

The wafers are made of a finely graded mixture of clay, talc and barium carbonate called steatite. Three slightly different forms are stamped, for carrying different components. After a wafer is stamped out by a heavy press, it is conveyed through a kiln at up to 2,300 degrees Fahrenheit. The wafers are then run through a gauging machine which rejects all that do not fall within the prescribed dimensions.

Meanwhile the resistor, capacitor and inductor elements are being prepared by other machines. The resistor material is formed by spraying a carbon mixture on asbestos tape and coating it with a plastic film; more than 10,000 resistors can be cut from a single roll of this film. The capacitor elements may be of a ceramic material, plastic tape or glass. The ceramic type, the only one thus far in production, has as its insulator a tiny slab composed of high-purity titanates. Inductor coils are printed on tiny cylinders.

The wafers and the components that will be mounted on them are all fed in proper order into the automatic production line. In the first stage of operations silver circuits are printed on wafers and conducting surfaces on ceramic capacitors. The printed pieces are then passed through a furnace to increase the silver's conductivity and bond it to the ceramic. Finally the pieces are dip-soldered by machine, a thin coating of solder clinging only to the printed pattern. An electronic machine, set up with the appropriate test circuits by punch cards, tests all conducting circuits and rejects faulty ones.

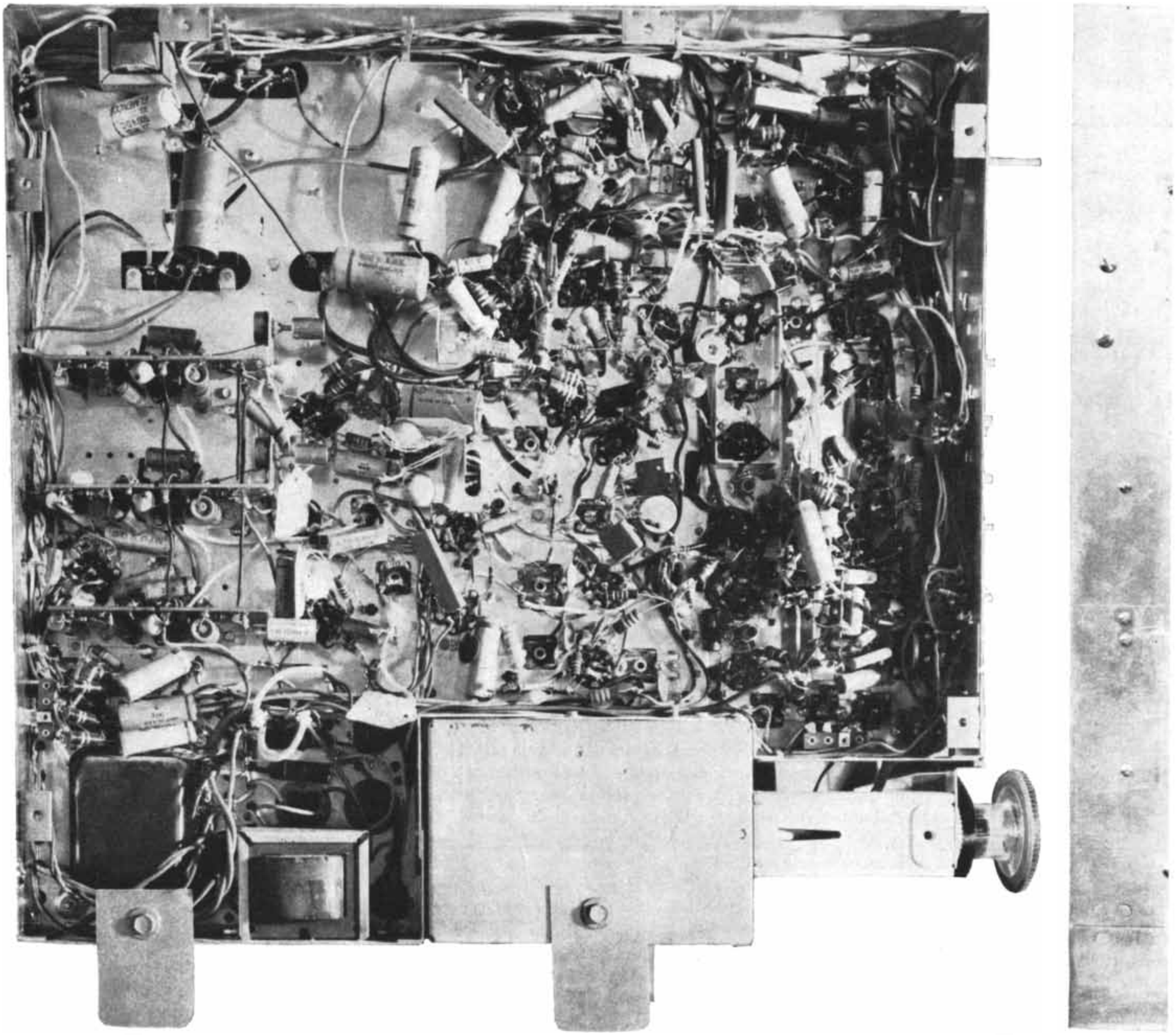
Next a series of automatic operations mounts the proper electronic components on the printed wafers. Resistors are applied in a machine which snips half-inch lengths from the narrow roll of resistor tape and applies these strips under pressure, usually two strips to a side, precisely between the printed electrodes on the wafers. Tape capacitors are applied in the same way, while the ceramic type is handled in a machine which bonds the capacitor to the wafer by induction heating. Plastic tube sockets are soldered to the wafer circuits by another machine.

Finally the mounted and machine-tested wafers are assembled into finished modules in a large machine which stacks and holds them in a jawlike device and connects them by fine riser wires soldered into the edge notches. At the tube-socket end 12 short leads are left for attaching the whole module to a larger assembly. The completed module is put through rigorous tests and accepted or rejected in a machine which sequentially compares its performance with that of a standard circuit. Then the whole module is dipped in a protective plastic coating.

This production system, it will be noted, is neither completely integrated nor continuously automatic. It loosely organizes its operations about groups of automatic machines, separately designed for making the basic components, printing the circuits, installing the components and assembling the final product. Workers transport materials to and from these groupings, and operators are required to watch over the various machines. But this looseness of organization makes for a flexible system which is capable of more fully automatic development.

The product is a rugged unit capable of being built into almost every type of electronic equipment except computers, for which it does not yet have a suitable range of components [*see photograph of a typical module assembly on page 31*]. The module is already wired and ready for mass installation. One thousand modules can be stored in 10 cubic inches of space. The unit gives higher circuit quality and longer life to electronic equipment. And repairs are simplified, for instead of hunting down a burned-out resistor or capacitor, it is only necessary to find the general circuit area where the trouble lies and replace the module.

The machines designed by the Bureau of Standards and the necessary control equipment were built by industrial contractors, chief among them the Kaiser Electronics Division of the Willys Motors, Inc., which set up and operated the pilot plant under a Navy contract. By 1953 enough operating experience and cost data had been accumulated to prove the process practicable. Its main use so far has been for military purposes. But



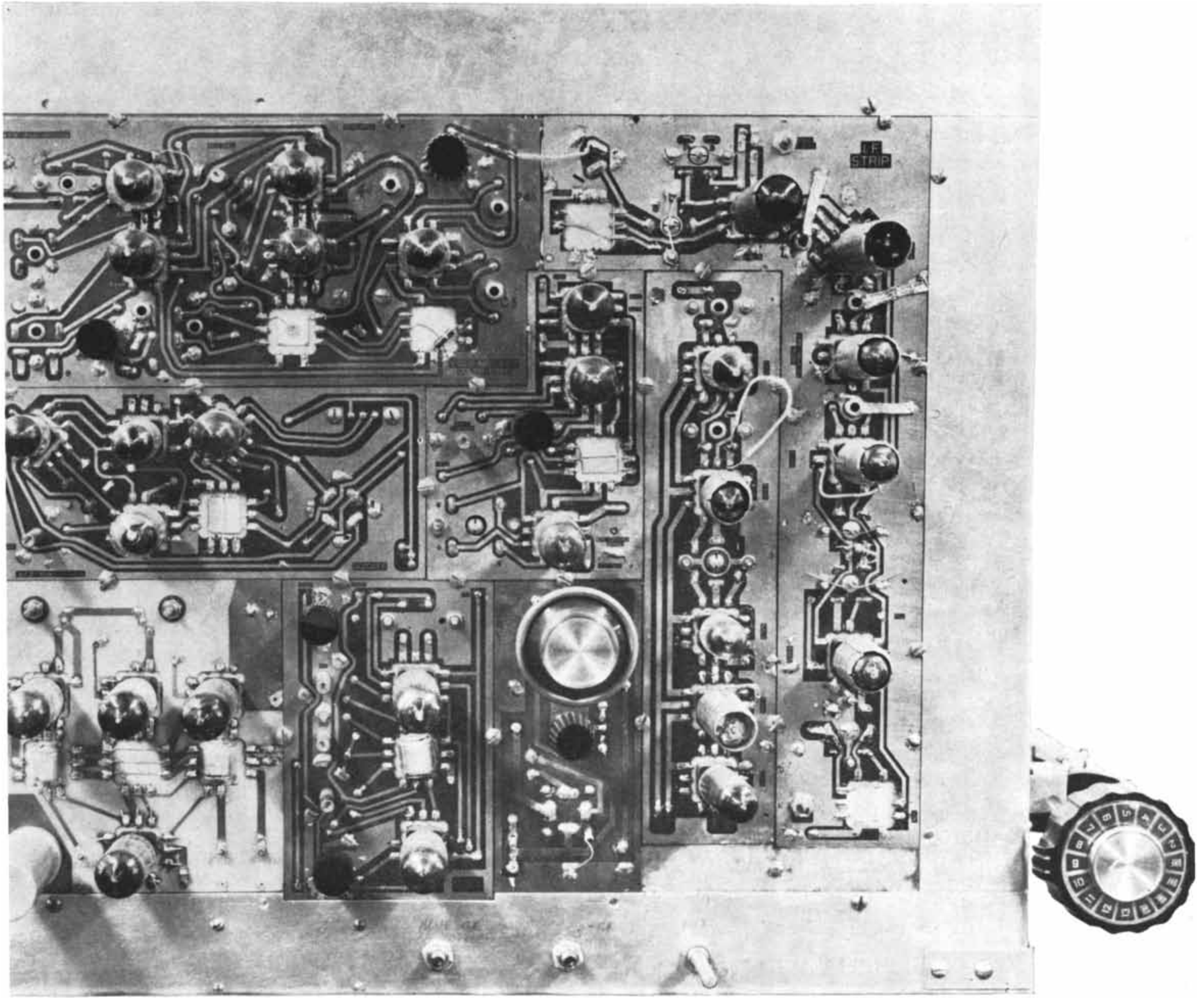
COLOR TELEVISION CIRCUIT made from conventional parts is shown at the left. At the right is a similar circuit as executed in modular design. The conventional circuit is seen from below; its vacuum tubes and few other prefabricated parts are on the top

ACF Industries, Inc., recently became interested in the process. It took over the 60-odd Bureau of Standards engineers and technicians associated with the project, including Reid and Henry, and set them up in a new operating division called ACF Electronics to bring the process to commercial production. The group has now spent more than a year and $1 million redesigning the equipment into an improved, full-scale production line in Alexandria, Va. Within a few months it will be turning out about one million modules per month.

The company proposes to supply radio and television manufacturers with circuit units built to their specifications. To show what can be done, it has converted a number of conventional electronic items to modular construction, among them an automobile radio and an experimental television receiver.

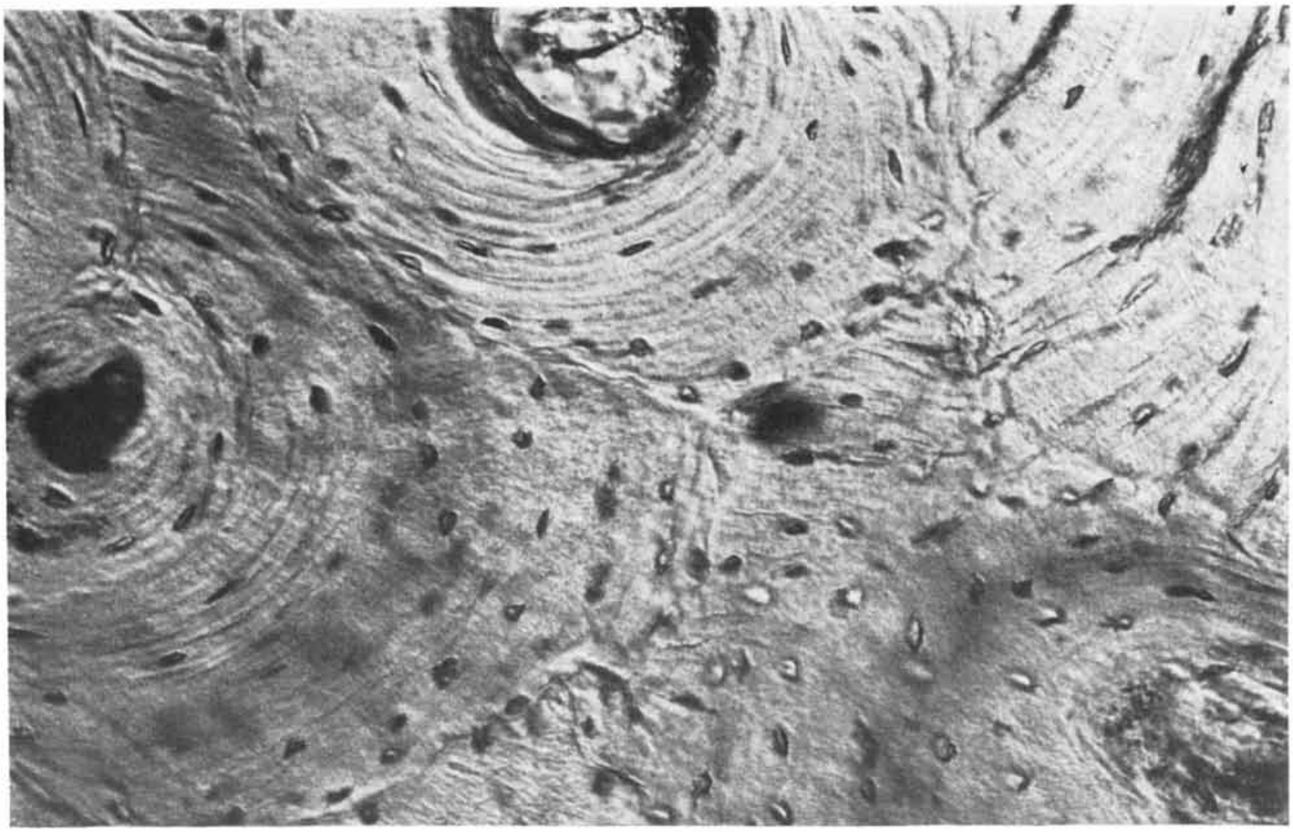
The main advantage of modular construction in the mass production of radio and television is its radical simplification of assembly procedures. This is strikingly illustrated in the experimental television set designed by ACF Electronics. It reduces the number of parts that have to be assembled by about 70 per cent: 17 modules replace 153 parts of a conventional set. In color television the reduction of complexity is even more striking.

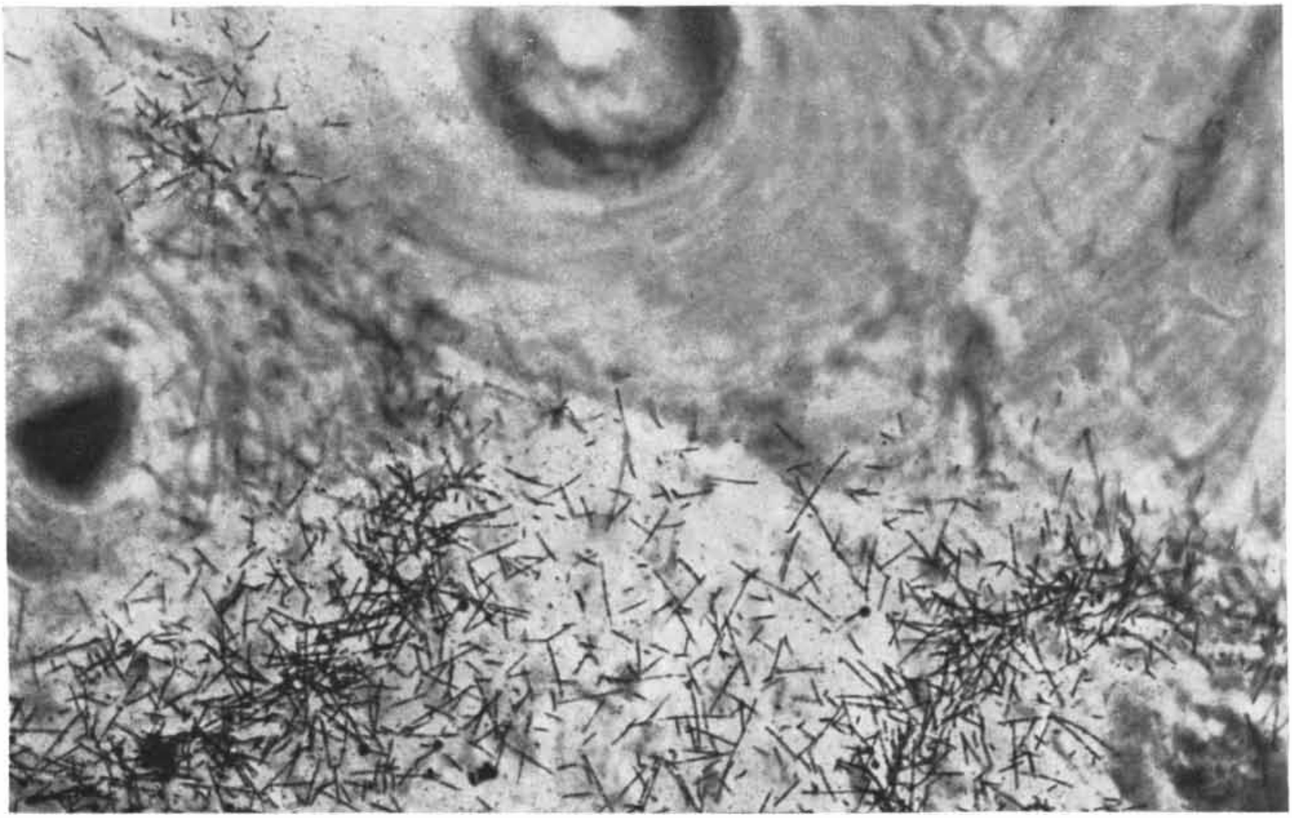
As the electronic module system develops in practice, its separate stages may be linked together into a continuous, self-feeding, self-regulating production line or automatic factory. In industry generally full automation undoubtedly will come by such gradual stages. It seems only appropriate that electronics, which has provided the controls and concepts that make automation possible, should be the first industry to reduce these concepts to practice.



side of the chassis. The modular design puts all parts of the circuit on one side, the tubes plugging into the tops of the modules.

This experimental model was built by ACF Industries, Inc., which has begun to apply modular design to commercial electronics.





RADIUM POISONING is illustrated by these two photomicrographs. The top photomicrograph (magnification: 300 diameters) shows a section of bone from the upper arm of a 48-year-old woman who had died in 1951 as a result of a tumor induced by radium. She had been given radium water 22 years previously for the treatment of an arthritic condition. In the bottom photomicrograph a thin sheet of photographic film has been affixed to the same section of bone and developed. The tracks of alpha particles from the decaying radium atoms in the bone are visible as short, needlelike streaks in the film. The photomicrographs were furnished by W. B. Looney and Lois A. Woodruff of the Argonne National Laboratory. They were made by A. S. Tracy of its Biological-Medical Division.

Radioactive Poisons

The term refers to those radioactive atoms and molecules which, when they enter the human body, tend to accumulate in certain organs and subject them to damaging radiation

by Jack Schubert

Man was created in a radioactive world. We are bombarded constantly by cosmic rays from outer space and by radiations originating within the earth and ocean. The food we eat and the air we breathe are laden with minute but measurable amounts of radioactive isotopes. As a result we ourselves contain naturally radioactive atoms in every cell of our bodies. What has protected the human race up to now is that the total exposure to natural radioactivity during a lifetime is very small. In a sense, then, our present concern about radioactive "poisoning" arises from the fact that the age of man-made radioactivity has raised the exposure to a higher level. Unfortunately radioactive poisons are far more difficult to cope with than the ordinary chemical poisons we have known. They are incomparably more potent (the toxic dose is usually so small it cannot even be weighed), and they may produce a slow, insidious disease of which the victim is not aware until many years after the exposure.

Consider these facts. Sodium fluoride, one of the most potent chemical poisons, may be lethal to a man at a dose of one gram. But as little as one half-millionth of a gram of radium in the body has been known to kill a human being. Amounts of this order may not kill immediately but may cause bone cancer, which develops years after the radium has entered the body.

Radioactivity is measured in curies: one curie is equal to the radioactivity from one gram of radium (37 billion atoms disintegrating per second). Thus a millionth of a curie, acting on the body over a period, is a dangerous dose. From the discovery of radium in 1898 until the present, the total production of radium has been about 1,500 grams (1,500 curies). But today our chain-reacting piles produce fission products whose total radioactivity runs into hundreds of millions of curies.

Man was slow to realize the hazard of radioactivity. Probably the first human death from acute radioactive poisoning was reported at a meeting of the Berlin Medical Society in 1912. A 58-year-old woman suffering from arthritis had been treated for the disease with frequent injections, for 16 days, of thorium X, a short-lived isotope of radium. Within a month afterward she died, showing symptoms now recognized as those of radiation sickness, including hemorrhages and diarrhea. Eight years earlier Pierre Curie had observed that laboratory animals died within hours after breathing the radioactive gas radon, emitted from radium during its decay.

But these danger signals went unheeded. Between 1915 and 1930 thousands of people in the U. S. actually ate or drank radium. Patients wealthy enough to afford this "cure" took radium water or injections of radium salts for all sorts of diseases. One physician alone administered radium salts to about 5,000 patients. An emaciated 52-year-old patient, admitted to a hospital, related that he had drunk a two-ounce bottle of water containing two micrograms of radium each day for about five years. All in all he had consumed 1,400 bottles! Post-mortem examination disclosed that his skeleton contained 74 micrograms of radium. Few persons anywhere had any notion of the deadliness of this novel substance. In Europe a candy firm marketed radium-containing chocolate bars. We may laugh at that age of innocence, but we cannot be too smug even today. As late as 1953 a company in the U. S. sold contraceptive jelly incorporating nearly a microgram of radium in each two-ounce tube!

The tragic case of the New Jersey watch-dial painters finally aroused the world to the necessity of examining the biological effects of radioactivity. For eight years girls in a New Jersey factory painting luminous dials with radium had followed the practice of pointing their brushes with their lips. The first indication that they had been poisoned by the radium was discovered in 1924 by a dentist, Theodor Blum, who treated many of the girls for severe jaw infections caused by bone destruction. By 1929 15 of the girls had died. Meanwhile they had been subjects of the first intensive and systematic study of chronic radioactive poisoning in human beings, carried out by Harrison Martland, the Medical Examiner of Essex County.

Many other studies followed. One of the obvious areas for investigation of radiation hazards was the uranium mines, the source of radium. It had been known even before the discovery of radioactivity that in the uranium mines of Joachimsthal in Bohemia more than half of the miners died of lung cancer. The opening of a particularly rich vein of pitchblende was always followed by an increased death rate some years later. Measurements of radioactivity in the mines showed that the level was some 30 times what is now considered the tolerance dose.

The newer uranium mines now being worked in the U. S., on the Colorado plateau, have about the same radon concentrations as those in Germany, but U. S. Government agencies have taken steps, particularly improved ventilation, to reduce the hazard.

Man can learn to live even with the tremendous amounts of radioactivity

	ELEMENT	TOTAL RADIOACTIVITY (MICROCURIES)	ATOMIC DISINTEGRATIONS (PER MINUTE)
		(TOTAL IN BODY)	
MAN	POTASSIUM 40	.1	220,000
	CARBON 14	.06	130,000
	RADIUM 226	.0001	200
		(PER KILOGRAM)	
OCEANS	POTASSIUM 40	.00025	560
	CARBON 14	.00000013	.3
	RADIUM 226	.0000001	.2
	URANIUM 238	.0000005	1.2
	RUBIDIUM 87	.0000036	8
		(PER KILOGRAM)	
SOIL	RADIUM 226	.0001-.001	200-2,000
	ALL OTHER RADIOISOTOPES FROM URANIUM, THORIUM, POTASSIUM	.001-.01	2,000-20,000
		(PER KILOGRAM)	
FOOD	RADIUM 226	.000001-.000005	2-10
		(PER LITER)	
WELL WATER	RADIUM 226	.000005	11
		(PER LITER)	
SURFACE WATER	RADIUM 226	.00000003	.07
		(PER LITER)	
ATMOSPHERE	RADON 222	.0000002	.5
	RADON 220 (THORON)	.00000001	.02

NATURAL BURDEN of radioactive isotopes is tabulated. The amount of radium 226 in newborn infants is only .00000003 microcurie. The well water for which a figure is given is from an area in Illinois. The atmosphere also contains tiny amounts of other isotopes formed by reactions involving cosmic rays: carbon 14, hydrogen 3 (tritium) and beryllium 7.

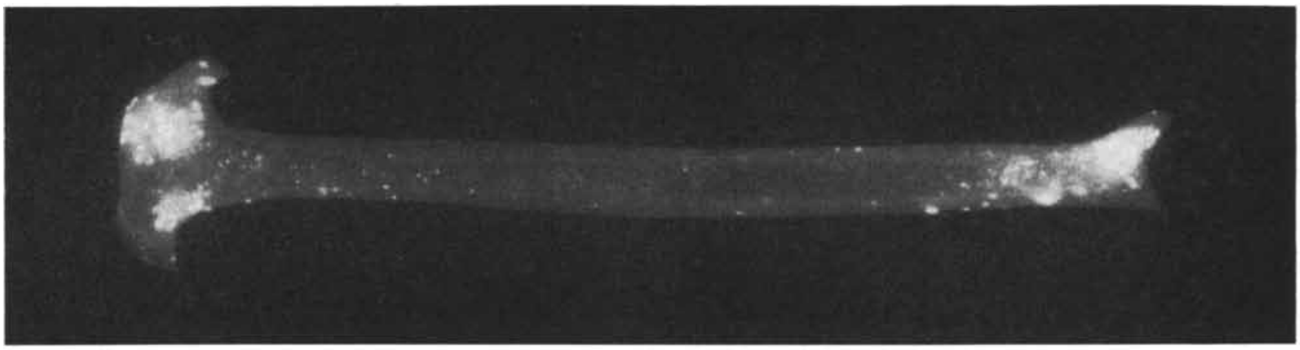
RADIOISOTOPE	HALF-LIFE	PRINCIPAL RADIATION EMITTED	MAXIMUM PERMISSIBLE AMOUNTS (MICROCURIES)		
			TOTAL BODY	WATER (PER LITER)	AIR (PER LITER)
PLUTONIUM 239	24,400 YEARS	ALPHA	.04	.0015	.000000002
RADIUM 226	1,620 YEARS	ALPHA	.1	.00004	.000000008
POLONIUM 210	138 DAYS	ALPHA	.04	.003	.0000004
STRONTIUM 90	19.9 YEARS	BETA	1	.0008	.0000002
CALCIUM 45	152 DAYS	BETA	13	.25	.000006
CARBON 14	5,600 YEARS	BETA	250	3	.001
PHOSPHORUS 32	14.3 DAYS	BETA	10	.2	.0001
IRON 59	45.1 DAYS	BETA	11	.1	.000015
IODINE 131	8.1 DAYS	BETA	.3	.03	.000003

NINE RADIOACTIVE ISOTOPES are among the potentially more hazardous. The maximum permissible amounts are for continuous exposure to a soluble form of each isotope. The maximum permissible amounts for carbon 14 apply to its intake as carbon dioxide.

that have been released by the discovery of nuclear fission. The best evidence of this is the excellent safety record of the U. S. atomic energy enterprise. In 10 years there has not been a single radiation injury at Hanford, where some 9,000 men and women have worked on the production of plutonium, perhaps the most dangerous of all the new radioactive poisons. But as time goes on, and radioactive materials accumulate on our planet, the problem will become less and less simple. Safety so far has been bought at the price of the strictest possible precautions against exposure, and it has been achieved only because mankind has been extremely gingerly and limited in its use of radioisotopes. To handle them with complete safety and confidence we shall need to learn much more precisely than we know now what the permissible limits of exposure are, how the various radioactive poisons affect the body and how such poisoning can be prevented or cured.

Radioactive substances emit two kinds of radiations which particularly concern us: alpha and beta rays. Alpha particles are harmless when they strike the outside of the body; since they cannot penetrate more than about 50 microns into tissue, they are absorbed by the dead outer layers of the skin and do not reach living cells. Beta particles, which can travel several millimeters through tissue, may burn the skin, but they do not penetrate as far as the vital inner organs. It is when they get inside the body, through breathing, swallowing or entry into the bloodstream, that the radioactive poisons are most dangerous. Within the body the radioactive substance comes directly into contact with living cells, and even the short-ranged alpha particle may pass through five cells before it reaches the end of its trail. Here the massive alpha particle is far more damaging than the beta particle. Either type of particle, however, may injure the cells. Fortunately the cells have a remarkable capacity for self-repair, but if they are subjected to insult or injury for a long enough time, they will finally die or give rise to cancer-producing cells.

The most dangerous radioisotopes are those that stay in the body, instead of being quickly excreted, and have a long enough half-life to keep bombarding the cells with particles for months or years. One of the most hazardous, for instance, is plutonium: it tends to lodge in the bones, is excreted very slowly, and has a radioactive half-life of 24,000 years,



LEG BONE OF A DOG which eight and a half years earlier had been injected with the radioactive isotope strontium 90 was mounted in a block of plastic and sliced down its long axis. The cut section of the bone was then placed in contact with a sheet of special photographic film. When the film was developed, it showed both diffuse exposure and "hot spots" that were due to the radioactive strontium. This radioautograph was furnished by Miriam P. Finkel and Juanita Lestina of the Argonne National Laboratory.

emitting destructive alpha particles. On the other hand, radioactive iodine (the isotope iodine 131) may be kept in the body for a long time but is not very dangerous because its radioactive half-life is only eight days; within two months almost all of it will have decayed and ceased to be radioactive even if none is excreted. In some cases the tenure of the poison in the body depends on the form in which it is introduced. For example, if carbon 14 (radioactive half-life: 6,000 years) is injected into the bloodstream in the form of carbonate, most of it is eliminated within a matter of minutes, but if the radiocarbon is incorporated in a molecule which the body does not break down readily (*e.g.*, certain dyes), it may take years to eliminate all the carbon 14. So the hazard of a given radioisotope depends basically on a composite quantity called the "biological half-life"—a measure of the duration of its activity within the body.

A radioactive poison entering the body may at first be excreted very rapidly in the feces and urine. But after about a week the excretion rate falls, and the body may then take years to rid itself of as much of the radioisotope as it did during the first week. Most fission products are known as "bone-seekers": they tend to concentrate in the skeleton. Radium and strontium 90 have this tendency because they resemble calcium in chemical behavior. Plutonium, which is insoluble in body fluids, is stored not only in bone but also in the liver, spleen and other soft tissues. A particularly malignant feature of some of the radioisotopes is their tendency to concentrate in "hot spots" instead of distributing themselves evenly through the bone or other tissue they invade [*see photograph above*]. Plutonium, which is two and a half times as toxic as radium, may owe its greater toxicity to the circumstance that it forms more intense hot spots or concentrates in more sensitive tissue centers.

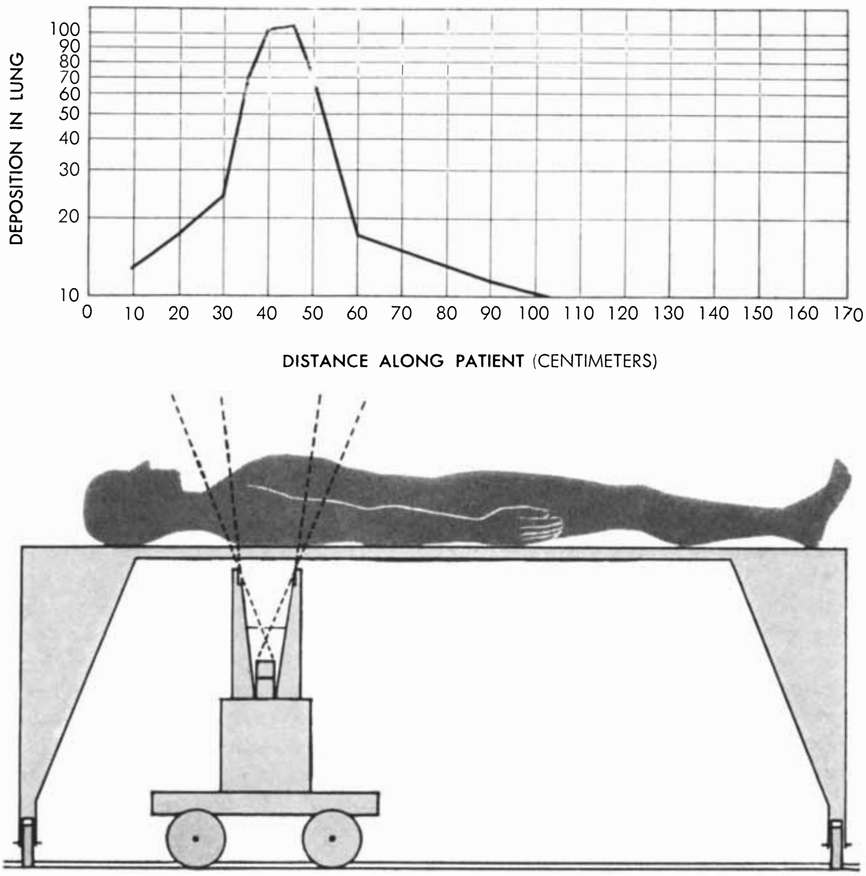
Radioactive dust breathed into the lungs is a great hazard. Fortunately the lungs have some defense: the upper respiratory tract efficiently eliminates most foreign particles by propelling them into the mouth so that the particles are swallowed and excreted. English coal miners, who during their average 39-year lifetime of work in the mines inhale about seven pounds of dust, were found to have less than one ounce of dust retained in their bodies at death. However, insoluble dust particles of certain sizes—particularly those about one micron in diameter—do tend to collect and stay in the lungs.

To learn how to live and work comfortably in a world in which radioisotopes are being produced in great quantities, we must begin by determining how much exposure the body can safely tolerate—*i.e.*, the maximum permissible amount (MPA) for each radioisotope. How much can be allowed in our air, water and food? We cannot avoid exposure altogether, for if we set the tolerance levels too low, it would be impossible to produce or use radioactive substances at all.

The estimation of the MPA is a complicated business. It involves the uptake and retention by the body of various radioisotopes in various chemical forms, their relative concentration in different parts of the body, the comparative sensitivity of different tissues, the energies and damaging effects of various kinds of radiation, and so on. As if all this were not enough, we also must consider the age of the exposed person. The bone-seeking radioisotopes related to calcium, such as strontium, barium and radium, concentrate to a greater extent in growing bone. Young, growing tissues are generally more radiosensitive. And the hazard is also greater for younger people because it may take 20 years or more of exposure for the body to develop cancer.

The present permissible levels have been fixed by the National Committee on Radiation Protection, which is sponsored by the National Bureau of Standards in cooperation with radiological organizations in the U. S. and abroad [*see lower table on opposite page*]. Some information has been gained from experiments on animals, but the standards are based mainly on the past 50 years of experience in exposure of people to X-rays, gamma rays and other ionizing radiation and on accidental cases of radioisotope intake.

For example, one tenth of a microcurie of radium 226, distributed throughout the skeleton, is stated to be the maximum permissible amount of that isotope because no individual with this amount of radium in his body has ever suffered detectable harm. One person with 3.5 microcuries of pure radium 226 in his body died of leukemia with accompanying bone damage. Hence the MPA for radium in effect at present apparently provides a "safety factor" against serious damage of 35. If in the future as little as two tenths of a microcurie is found to have injured an individual, or if a large number of people is found to be unaffected by as much as one microcurie of radium, the MPA may very well be lowered or raised, as the case may be. Generally a safety factor of at least 10 is applied. It must be emphasized that an individual who has somewhat more than the MPA of a radioisotope in his body is not necessarily in danger. Besides the tenfold safety factor, there are great variations in individual susceptibility: one patient with 23 microcuries of radium stored in his body was in better health



SCINTILLATION COUNTER mounted on wheels is used to detect the concentration of radioactivity in various organs of a patient. In the case illustrated by the curve at the top the patient had inhaled an insoluble salt of radium. The concentration of radium in the lung is shown by the increased counts as the counter traveled along the length of the patient.

than another patient who had 1.5 microcuries.

How does one measure the amount of radioisotope in a person's body? It is easy enough when the patient has died: all one need do is cremate the body and analyze a sample of the ashes by standard radiochemical procedures. This method has obvious disadvantages for application to a living person. The job can be done indirectly, however, by analysis of the urine, feces and blood. One of the earliest and best of these studies was made in Berlin nearly 45 years ago by J. Plesch. He injected small amounts of the short-lived radium isotope thorium X into two people and measured the amounts eliminated in the urine and feces during the next few days. He even went so far as to measure the radium excreted in their sweat: he had them wear long woolen underwear for 24 hours and then burned the perspiration-soaked underwear and analyzed the residue for radium. Apparently he recovered about one tenth of one per cent of the injected radium in the sweat secreted by a person in one day.

One of the most reliable methods for estimating the amount of radium in the body was introduced many years ago by Herman Schlundt, a chemistry professor at the University of Missouri. He found that the amount of radon in a person's breath is a good measure of the radium fixed in the body. Radon, an alpha-emitting daughter of radium, is easily measured by its radioactivity.

In the case of plutonium the usual measuring method is to analyze the urine: it is known that a few months after exposure the amount of plutonium present in a 24-hour sample of a person's urine is one 10,000th of the amount fixed in the body. At the Los Alamos Scientific Laboratory the urine of persons working with plutonium is analyzed periodically to make sure that they have not accumulated more than three hundredths of a microcurie.

The intake of radioactive dust into the lungs can be measured roughly by analysis of the feces, because the solid particles are coughed up, swallowed and passed through the stomach and intestines. Contamination of the air by radioisotopes can even be detected by analyzing swabs from the dust-filtering hairs in the nose.

When the radioisotope in the body is one that emits gamma rays, it can be measured directly by a Geiger counter or scintillation counter. The counter is simply passed over the patient's prone body, and it not only measures the amount of radioisotope in the body but also locates it [*see illustration at left*]. The method is valuable for detecting radium, because radium is a gamma-ray emitter. Moreover, it is so sensitive that it can identify different radioisotopes, if more than one is present, by the different energies of gamma radiation.

Much research has been done on the problem of removing radioactive poisons from the body. Promptness and speed are important, both to prevent the beginning of damage to the cells and to try to catch the isotope while it is still in the stomach or the bloodstream and has not yet migrated to a permanent lodging place in the bones or other tissues.

A person who has swallowed radium or strontium may be able to get rid of a large part of it in the feces by taking epsom salts or certain other substances which will react with the soluble radioisotope in the digestive tract and form an insoluble precipitate with it. Another possible and certainly more palatable approach is to eat rhubarb or spinach, which contain large amounts of oxalate—a good precipitating agent.

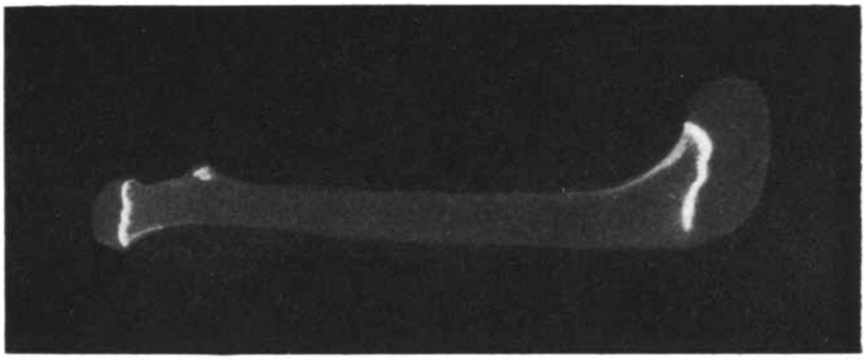
In experiments on animals Marcia White Rosenthal and the writer have been able to divert plutonium in the bloodstream from bone by injecting salts of certain metals, notably zirconium, titanium or aluminum, into the blood. The salts decompose, releasing insoluble particles of the metal hydroxides, and these soak up plutonium in the bloodstream much as a blotter soaks up ink. If the treatment is applied within an hour after the plutonium gets into the bloodstream, about half of it is removed in the urine within a day. Even if the circulating plutonium is not excreted, it is diverted from bone to other tissues.

After radioisotopes have left the bloodstream and become deposited in tissues, the situation is still not completely hopeless. Because radium behaves like calcium, one of the treatments that has been tried is a low calcium diet, or a drug, which hastens the removal of calcium (and radium) from bone. However, this decalcification therapy does not remove radium fast enough, and it cannot be continued indefinitely. A very promising newer approach, which unfortunately does not work for radium but may be effective in removing plutonium and rare-earth fission products, is the use of chelating agents [see "Chelation," by Harold F. Walton; SCIENTIFIC AMERICAN, June, 1953]. These metal-grasping compounds have been used successfully many times to remove mercury, arsenic and other metallic poisons, and they have now been found applicable to plutonium. The powerful chelating agent known as EDTA has a high affinity for plutonium and the rare earths, and when administered early it has removed as much as 25 per cent of the plutonium in a patient's body. Unfortunately it is not effective when the radioisotope has lodged in bone.

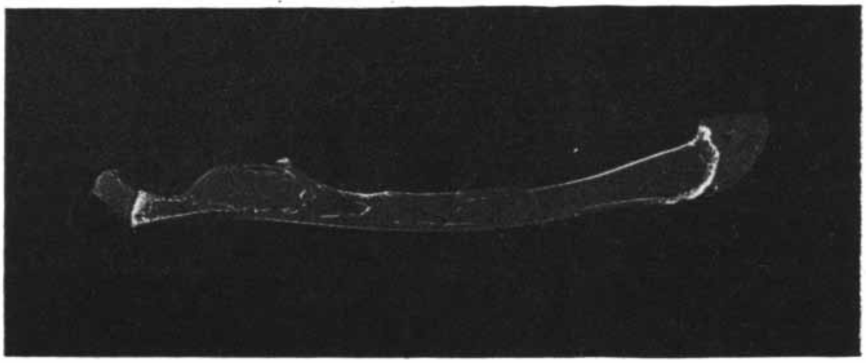
Perhaps the most effective treatment so far is a combination of zirconium salt and EDTA—the first to divert the radioisotope from bone, the second to remove the diverted poison from the soft tissues to which it has been sidetracked. One problem is that, since EDTA and the zirconium salt must be given intravenously, it does not appear practical to treat large numbers of people with these drugs for indefinite periods, as would be necessary in case of an emergency. One new approach that we are exploring is to induce the body to form its own chelating agents to capture radioisotopes. This may be done by alteration of the body's metabolism. It has been found possible to induce various tissues, including the spleen, blood and bone, to produce extra amounts of a fairly good chelating agent, citric acid.

On the whole, it is still the best policy to be supercautious in the use of radioisotopes. Their use in medicine is developing into a good-sized business, but it is questionable whether they should be employed as freely as they are for routine diagnostic tests of blood volume, liver and kidney function and so on, particularly where other tests are available. There are many reasons for caution. Certain radioisotopes such as iron concentrate in what are equivalent to hot spots in restricted regions of an organ. The injection of radioisotopes for routine diagnosis in pregnant women and babies seems particularly unwise, in view of the high radiosensitivity of embryonic tissue.

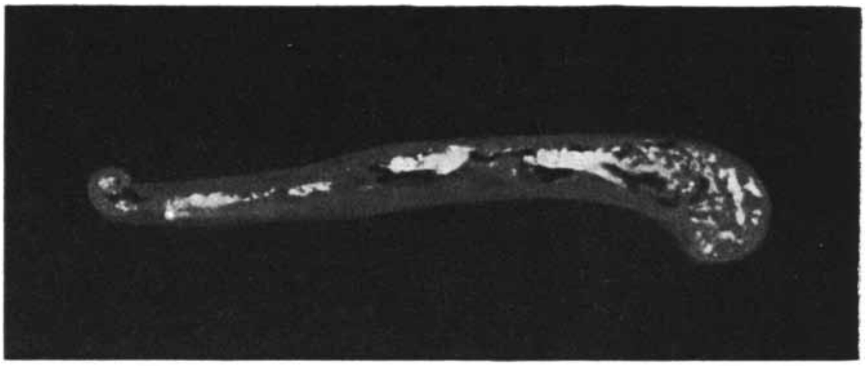
The administration of radioisotopes also involves a long-range, genetic risk. We have no information on the genetic effects in mammals of radioisotopes stored in the body. Here is an important area which needs to be explored.



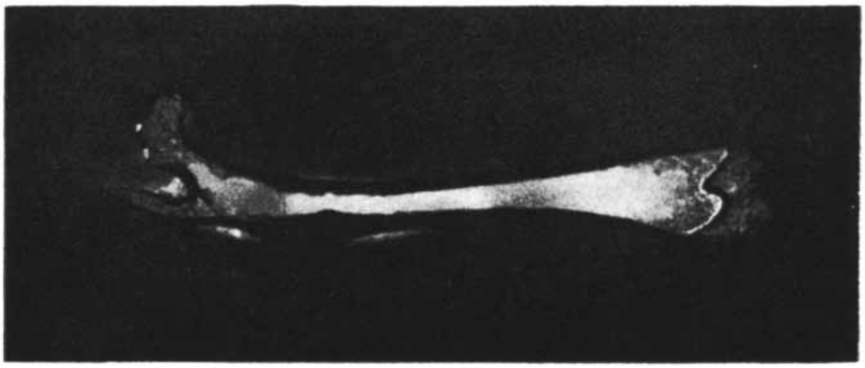
RADIUM was injected into a dog four days before this radioautograph of its leg bone was made. The radium has concentrated in the growing areas of the bone, especially the ends.



PLUTONIUM in the bone of a rabbit is shown by this autograph. The top two photographs were made by W. P. Norris and Lois A. Woodruff of the Argonne National Laboratory.



SODIUM BICARBONATE labeled with carbon 14 was injected into a rat. This radioautograph of a bone shows that the carbon 14 accumulated both in the bone and in its marrow.



DYE bearing carbon 14 in the central part of its molecule accumulated in the rat's bone marrow. The bottom photographs were made by A. Lindenbaum of the Argonne Laboratory.

LONG-RANGE WEATHER FORECASTING

Although predictions of a season or more still lack a sound basis, those of a week or a month are greatly improved. They rest on a deeper knowledge of huge waves in the atmosphere

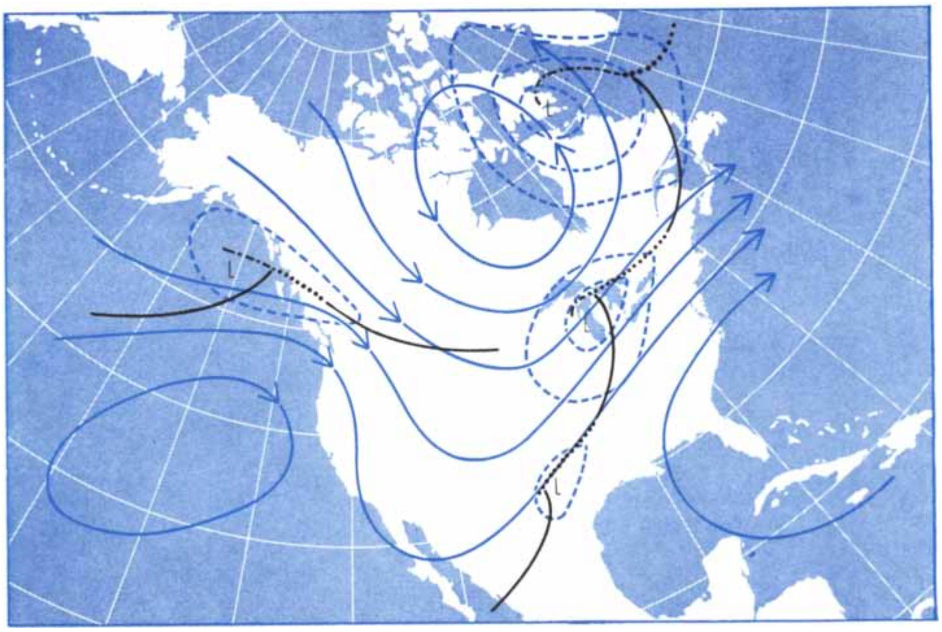
by Jerome Namias

Until a few years ago long-range weather forecasting was considered by meteorologists to lie in the fuzzy domain between science and mysticism. This view coincided to some extent with that of the general public, who, from long experience with the unreliability of predictions based on woolly bears' bands, groundhogs' behavior and other signs, could only conclude that scientific long-range forecasting did not exist. As far as predictions covering a season or more are concerned, there is still justification for this doubting point of view. But in forecasting for shorter periods, progress has been made. Weather estimates for about a week in advance are now routine, and 30-day predictions are used by thousands of businessmen.

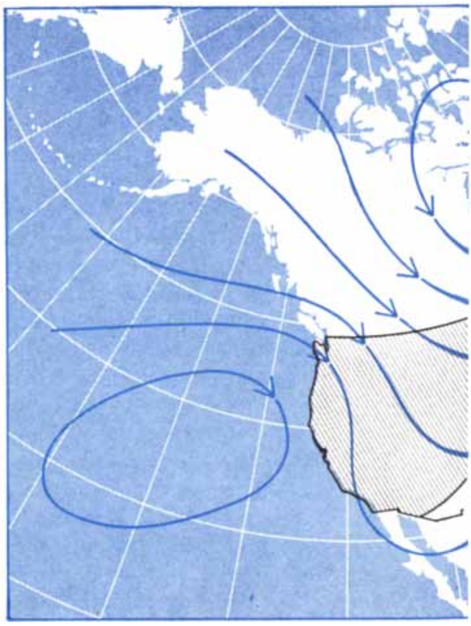
Both of these types of forecasts are still only of a general nature and far from perfect, because weather forecasting problems are among the world's most complex. Yet, while individual forecasts may often be wrong, over the past decade the U. S. Weather Bureau five-day and 30-day predictions have been correct a far higher proportion of the time than they would have been if merely based on chance or past weather records.

The program of research on long-range weather prediction began during the middle 1930s, when drought was transforming the central plains of the U. S. into a great dust bowl. To explore the possibility of predicting droughts, the U. S. Weather Bureau, the Bureau of Agricultural Economics and the Massachusetts Institute of Technology set up a joint research project. The investigators soon decided that a completely fresh approach was possible. Airplanes and balloons were beginning to map air movements at high levels in the atmosphere. And improved networks of communication provided a means of getting daily reports of conditions over a whole hemisphere. Thus the meteorologist's view was expanded both horizontally and vertically. For the first time it was possible to see the entire ensemble of atmospheric circulations that react with one another to produce weather.

The daily charts themselves were not



LONG WAVES at altitudes above 10,000 feet are traced by the solid blue lines on this map of North America. The flow of air is averaged over a period of five days. Low-altitude fronts associated with these waves are indicated by the key at left. Low-pressure areas are marked by broken blue lines.



PRECIPITATION associated with the long-wave pattern in the map at the left is represented by the cross-much help, for the 24-hour picture of storms and air movements was as chaotic as the eddies in a shallow river flowing over a rough bottom. The maps of air-flow at ground level offered few clues even when averaged over a whole month. But a similar averaging of air movements at higher levels brought to light some revealing patterns. At levels from 10,000 to 40,000 feet the new charts showed long waves or undulations, usually superimposed on a general west-to-east flow of air. In these long waves the flow resembles the sine wave of trigonometry. Each wave rises northward to a crest, then dips southward into a trough [*chart on opposite page*]. The core of the long wave, at the boundary of the stratosphere (generally between 30,000 and 40,000 feet), is the jet stream, where the currents may reach a speed of 300 miles per hour [see "The Jet Stream," by Jerome Namias; Scientific American, October, 1952].

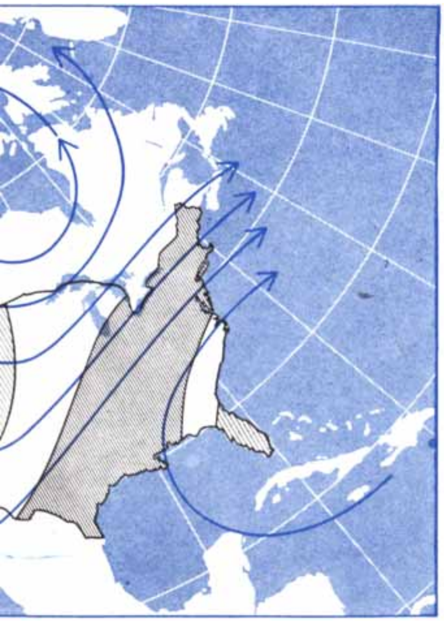
These upper air patterns soon became the center of attention in the long-range forecasting study. Since the long waves seem to be the principal mechanisms for deploying the major air masses of the earth from their sources in the polar and tropical regions, and since the movements of the air masses set the stage for the birth and development of storms, the waves offer the most promising means yet discovered for predicting flow patterns and future weather.

One of the earth's great air masses is generated in northern Canada, over a vast area which in winter is covered with snow. Another is produced over the Caribbean Sea and the Gulf of Mexico, whose waters are uniformly warm. These areas, and others like them, are great factories for the manufacture of bodies of air, covering thousands of square miles, with fairly uniform temperature and humidity in each layer. The structure of each air mass is so characteristic that meteorologists frequently can tell the source of one simply by studying its temperature and humidity at different heights. With the discovery of the long waves in the upper atmosphere, it became possible to explain how these air masses start to move away from their source regions and what determines their life history.

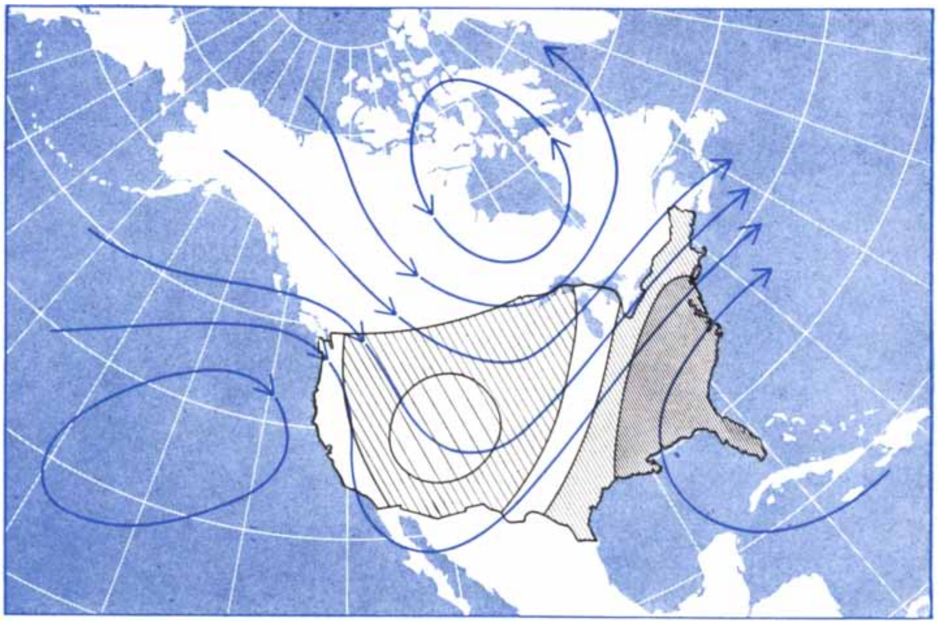
The long waves evidently serve as carriers for such masses. For example, the trough of a long wave moving from west to east over North America induces cold air masses to flow into it from the rear side. As the wave advances, it transports these masses eastward, and the course of the wave can often be followed by the high-pressure readings that signal the presence of the cold, dense air overhead. On the forward side, the long waves pick up bodies of warm air from the south; for example, air masses from the Gulf of Mexico may be set in northward motion by a trough advancing over the Mississippi Valley. The cold and warm masses meet on the eastern side of the long wave moving across the country from the west. Where these meet, they form the sharp boundary known as the Polar Front. A ceaseless struggle goes on at this front: the polar air masses are forever trying to thrust the tropical masses aloft and capture their domain. As a result of the conflict, cyclone waves form at the front. They usually appear as centers of low pressure on the daily weather map. As the long wave advances its front, generally moving easterly, it may produce a series or "family" of cyclones [*see chart on opposite page*].

Sometimes the air on the rear side of a trough may be warmer than that on its forward side. This condition arises over Europe when cold, eastward-moving air masses from the North Atlantic meet still colder air from western Siberia and Russia. But the more typical situation is the one in which there is warmer air ahead and cold air behind. The degree of temperature abnormality is in direct proportion to the length of the fetch of air entering the long-wave system. Very long fetches may carry Arctic air masses as far as the subtropics or bring tropical air masses into northern latitudes. These large-amplitude patterns are frequently associated with cold and warm spells during winter.

Once the pattern of long waves and of the flow of the upper air has been determined, it is possible to work out, in engineering fashion, a forecast of tem-



hatched areas. In general precipitation is heavy in front of the troughs of warm, moist air from the south. It is light behind the troughs carrying cold, dry air from the north.



MUCH ABOVE NORMAL
ABOVE NORMAL
NEAR NORMAL
BELOW NORMAL
MUCH BELOW NORMAL

TEMPERATURE at low altitude associated with the same long-wave pattern is also outlined by crosshatched areas. "Normal" is the average for the month. In general cold air from the north flows into the rear of the troughs. Warm air from the south is carried ahead of them.

perature for a week or a month ahead. But forecasting precipitation is more difficult. The best that can be done at present is to give some general indications. For example, it is usually safe to say that the air in the wake of a long wave trough, having come from the north, will be dry. As the polar air masses move southward and spread out, they sink and become warmer through compression; this makes the air's relative humidity still lower. On the other hand, the air in forward portions of the troughs, having come from the warm tropical oceans, is apt to be moist. When it flows upward over cold air masses, the ascending moist air is forced to liberate its moisture in the form of rain or, if it is cold enough, snow.

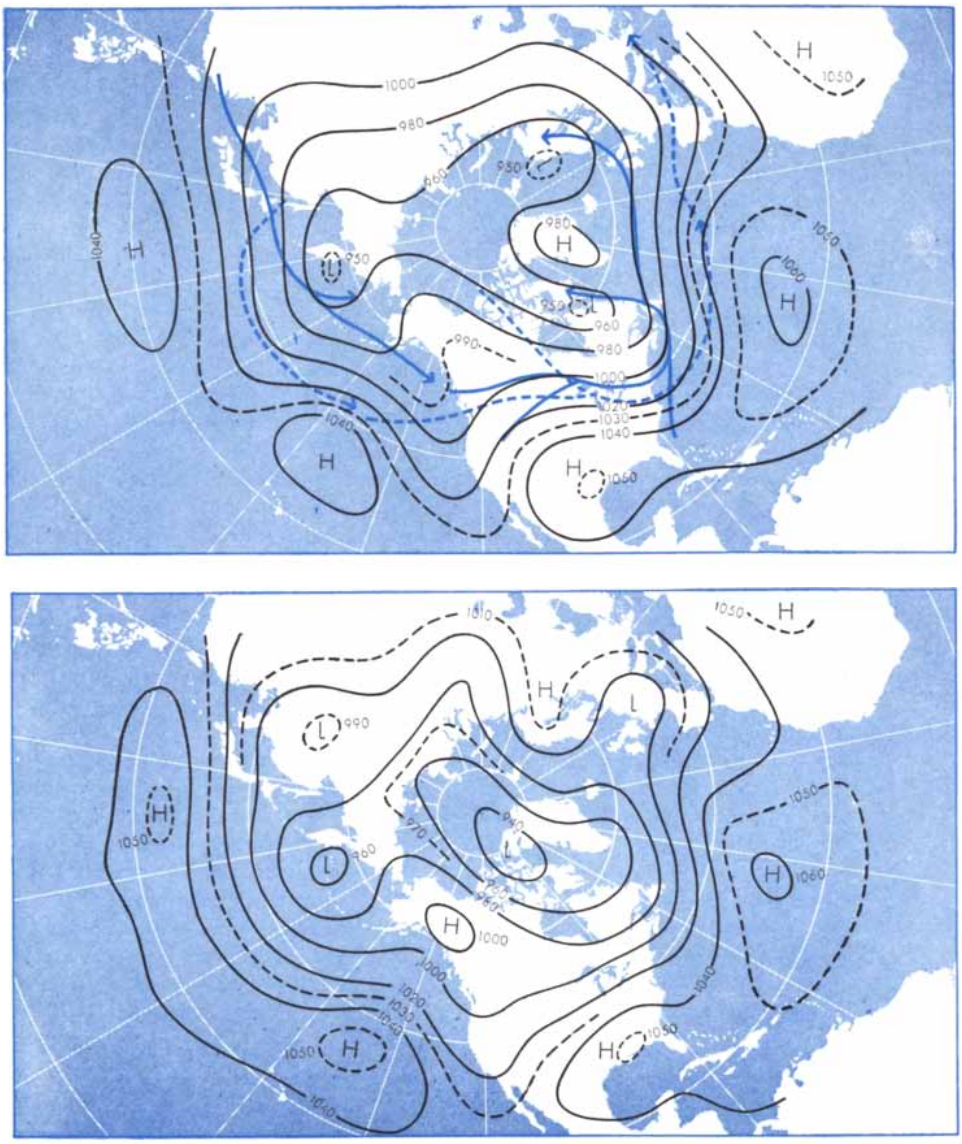
In general, then, precipitation is apt to be heavy in advance of troughs and light or lacking behind them. However, local factors, particularly in mountain regions, may promote or inhibit precipitation. Forecasting of precipitation is a complex business which involves relating the long-wave pattern to the local geography and climate, to experience and to a 20-year file of charts of circulation in the upper air.

Obviously the key to use of the long waves for forecasting lies in finding laws for predicting the waves' future movements and changes of form. The first work on this problem was carried on by Jacob Bjerknes of Norway and Carl-Gustaf Rossby of Sweden. Their work led to the concept that two factors determine how fast the waves will travel: the strength of the west winds in the layer involved and the length of the waves—the longer the wave, the slower it moves. For a given west wind drift there is a critical wavelength at which the waves will remain stationary, and they may even move backward (as waves) if they are long enough.

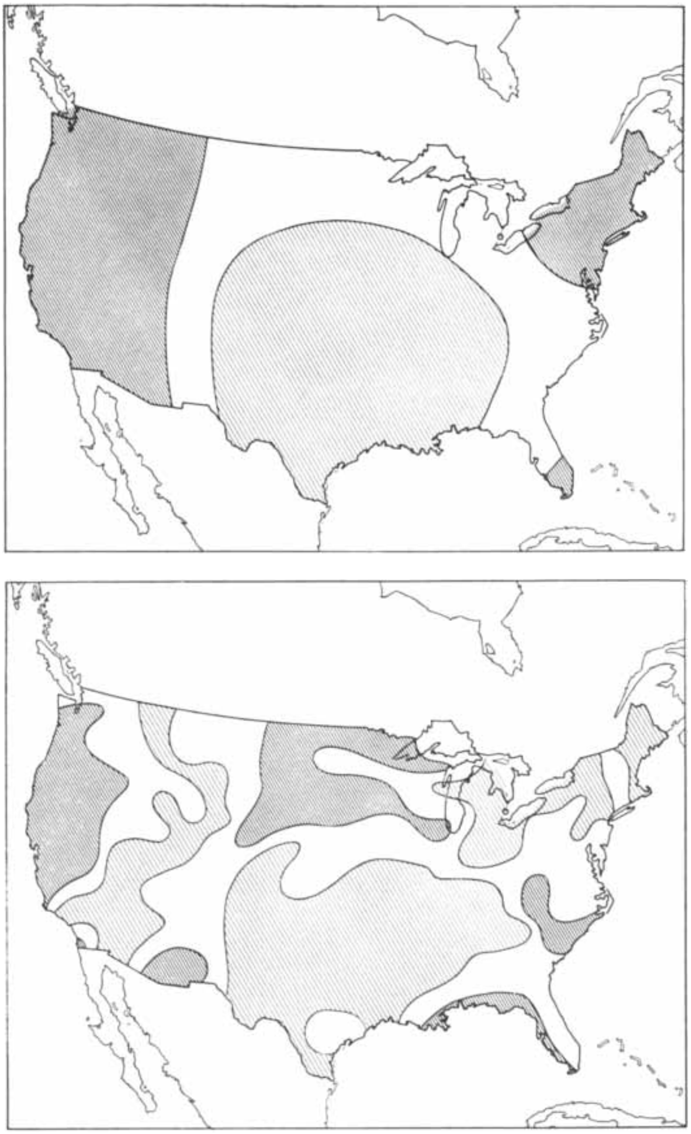
The development of this concept gave a tremendous impetus to both long-range and short-range forecasting and, indeed, ushered in a new era of meteorological thinking. But it was soon discovered that the real atmosphere behaves quite differently from the simplified model the theoreticians had had to use. The strength of the westerlies varies from level to level; the form and length of the long waves are sometimes hard to determine, and usually there is more than one set of waves, moving at different speeds, in a hemisphere. These and other complications made it necessary to work out many correction factors to apply in different areas, seasons and elevations.

The electronic computer has become a great aid on many of these problems. John von Neumann and Jule Charney at the Institute for Advanced Study in Princeton developed physical and mathematical models for the computer to work on, and the U. S. Air Force, the Navy and the Weather Bureau have just begun joint employment of it. With the help of the machine, complex problems can be solved in an amazingly short time. While the meteorological work with the electronic computer so far has been focused on the short-range (24- to 36-hour) forecast problem, there is reason to believe that it can be used for long-range work also.

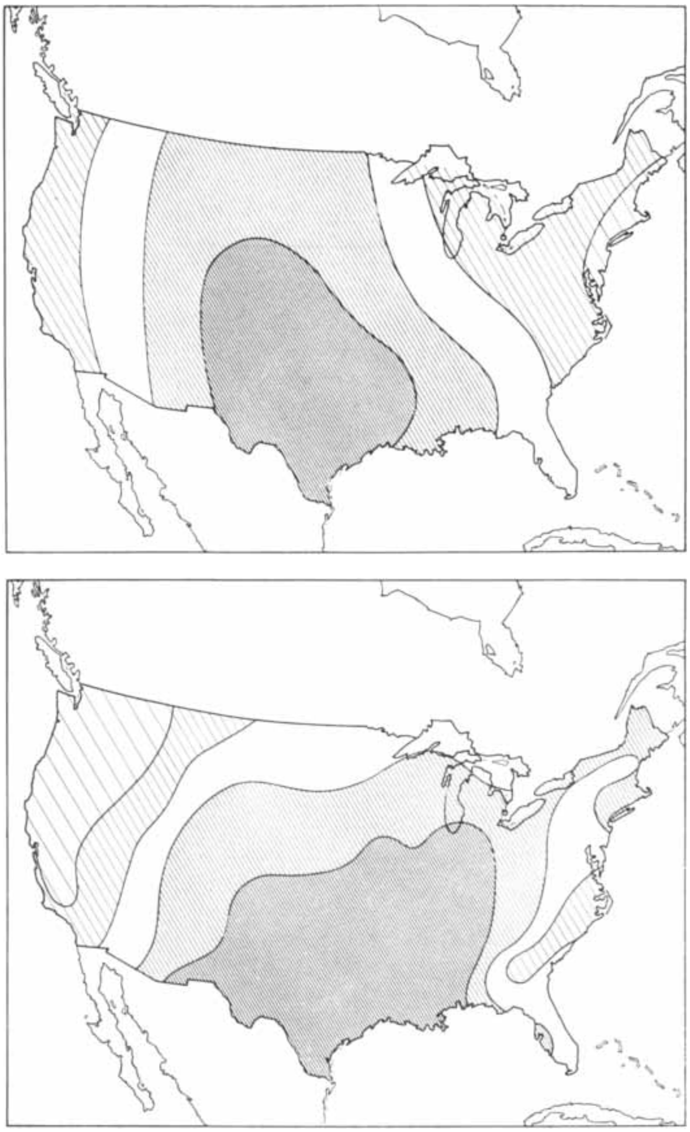
At present the only machines used in long-range prediction are of the punched-card variety. This equipment makes it possible to compute time-averaged charts quickly and accurately, and also to compute the instantaneous rate of motion of the long waves. The calculations tell the forecaster how the waves are behaving at the moment and suggest where and how they will lie if the trend continues. The basis of the method is the plotting of maps from a series of pressure readings. Imagine at some elevation a barometer which plots five-day averages each day and draws a smooth curve through these averages. The slope of the curve then gives a "tendency" which may be expressed quantitatively. If these tendencies are plotted for hundreds of points around



LONG WAVES FORECAST for June, 1953, are shown in the upper chart. The pattern actually observed is shown in the lower chart. The black lines denote the height in tens of feet at which a pressure of 700 millibars was predicted and observed.



PRECIPITATION FORECAST is essentially based on the long-wave pattern and long-term averages. The upper chart shows the prediction for June, 1953. The lower chart represents the actual observations.



TEMPERATURE FORECAST for the same month is shown in the upper chart. Observations are in lower chart. The Northeast got temperatures warmer than those predicted.

the hemisphere, and the points of equal value are connected by lines, the areas of rising and falling pressure are graphically depicted. When these tendency lines are superimposed upon the pattern of long waves, it is possible to compute the waves' speed, as well as their change of shape and length. In practice the tendencies are obtained with the help of statistically derived equations which automatically incorporate an estimate of local climatological effects that influence the development of the pattern.

This method yields a clear picture of the trends, which can be projected into the future. But for more accurate results the underlying physical factors—the speed of the westerly winds and the length of the waves—should be taken into account, for the relation between them will shape future developments. The forecaster can compare his tentative prognostication as to the movement of the waves with a theoretical calculation based on the wavelength and the strength of the westerlies. If the two calculations are in reasonable agreement, he can be fairly confident of the forecast. If they do not agree, he must review the various factors involved and decide on how much weight to give each one. Meteorologists hope that eventually electronic machine methods will eliminate this subjective phase of the work and will also permit physical rather than statistical estimates of how climatic factors will affect the development of long waves.

In the five-day forecasts an attempt is made to predict the weather map for each of the five days. This requires vivid imagination and experience, for it is something like trying to picture in detail the eddies which the basic current will produce in a shallow stream at some future instant. Obviously the day-to-day prognoses cannot pretend to be a play-by-play description of the weather at each point; they are merely guides to the expected pattern. In the 30-day forecasts, no such detail is even attempted; they outline the principal expected paths of low and high pressure.

Most of the industrial users of long-range forecasts are interested in the expected average temperature and total precipitation for the period. The forecasts of temperature are expressed on a five-part scale: (1) much above normal, (2) above normal, (3) near normal, (4) below normal and (5) much below normal. "Normal" means the average temperature in the particular place for the particular month over the past 30 years. "Much above" and "much below" temperatures are those so high or so low that they have been recorded only one eighth of the time; the "near normal," "above normal" and "below normal" temperatures have occurred one fourth of the time in each case. For example, a forecast of much-below-normal temperature for Chicago in June would mean that the average temperature is expected to be so cold that over the past 48 years only six Junes were of that order of coldness. The numerical limits defining these classes have been computed for many places in the country for each month. Of course they vary widely: "much below normal" means very different things in Florida and in Maine.

Precipitation is described in the 30-day forecasts as "light," "moderate" or "heavy." These terms, also based on past records, define in each case the amount of precipitation that fell one third of the time for the given month and place. Thus a forecast of light precipitation for Chicago in June would mean that it will have no more rain during the month than fell in any of the 16 driest Junes over the past 48 years.

A sample of a 30-day forecast, together with the actual weather that developed is illustrated in the charts on the preceding two pages. This forecast is chosen not because it was somewhat more accurate than the average but because it shows how the long-range method was able to predict a highly abnormal event—the great drought of June, 1953, in the Texas, Oklahoma and Colorado area. It also indicates the sensitivity of temperature and precipitation patterns to the form of the long-wave pattern.

The first chart shows the predicted pattern of air flow along the levels (around 10,000 feet) where the barometric pressure would be 700 millibars (equivalent to about seven tenths of an atmosphere). For example, over the West the prevailing flow was predicted to be from southwest to northeast; over the eastern U. S., from northwest to southeast. The forecast foretold the positions of the ridges and troughs of the long waves over much of the hemisphere fairly well. However, over the northeastern U. S. the prevailing flow turned out to be westerly, instead of northwesterly as predicted, and over Scandinavia there was a ridge instead of a trough. In the case of the U. S. Northeast, the wave shunted cold polar air masses eastward instead of deploying them southeastward, so that the area did not get the predicted cool weather; instead it got warm air masses from the central plains. Since these warm air masses were not forced aloft by cold air, as had been expected, the forecast was also in error in its prediction of heavy precipitation for the Northeast. Scandinavia, because it had a ridge instead of a trough, had a warm, dry June in place of the predicted cool, wet weather.

Yet the good portions of the forecast overshadow the bad. The much above normal and above normal temperatures over the southern and central U. S., as well as the cool weather in the Far West, were correctly predicted. So was the large area of light precipitation. The upper air picture shown here was most unusual; such a pattern had not been observed in the U. S. in 17 years (since 1936). Its accuracy in forecasting the unusual drought therefore was a gratifying indication of the power of the long-wave method.

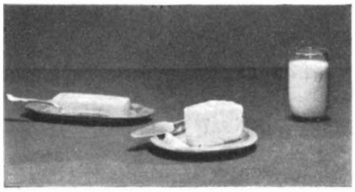
To be sure, there are times when the atmosphere seems to assume a chaotic character not easily analyzed in terms of the long waves. During these periods the general circulation and the associated weather regime seem reluctant to settle down into a steady pattern. Perhaps in such cases we shall need to choose other time intervals for averaging. The new electronic machine methods also may help in clarifying such problems.

ANALYSIS ROOM of the Extended Forecast Section of the U. S. Weather Bureau in Washington is hung with scores of carefully annotated maps. These are first made from reports four times a day from more than 1,000 weather stations all over the world. After statistical analysis new maps are drawn from which the forecasters interpret trends and make their long-range predictions twice a week.

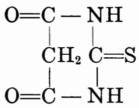
Kodak reports to laboratories on:

how to spot bad cheese . . . 500 facsimiles of your precious sheet of paper . . . news for those who dye

For Barbara



According to a charming tale, the great von Baeyer named barbituric acid for Barbara, a friend of his. Then someone came along and replaced one of its three ketonic oxygens with sulfur, creating 2-thiobarbituric acid.



Then someone else added 2-thiobarbituric acid to fructose and got a yellow precipitate. Then some medical school people obtained an entirely different orange-red precipitate by reacting 2-thiobarbituric acid with incubated brain tissue and proceeded to prove that the reaction was with a 3-carbon fragment of an oxidized double-bonded fatty acid moiety of the lecithin in the tissue. Then some dairy chemists conceived the idea that this property of 2-thiobarbituric acid might make a convenient test for oxidative deterioration in fats. Then some agricultural chemists worked out the details for using 2-thiobarbituric acid to find out objectively when cheddar cheese has gone bad. Or powdered whole milk or butter. Then we prepared a procedural abstract of their method to give away in order to help us sell our *2-Thiobarbituric Acid* (Eastman 660) at $2.25 for 25 grams.

Want the abstract? The chemical? A copy of Eastman Organic Chemicals List No. 39 of some 3500 organics we stock? Write to Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).

1½ minutes and 18¢ to publication

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Please be preconditioned

Because these reports are written for readers with a scientific turn of mind, we should like to discuss in some detail the chemistry of the new *Eastofix Dyes* which we have just announced to the textile industry as a solution for the hitherto insoluble problem of piece-dyeing acetate fabrics to a wash-fastness, lightfastness, and gas-fastness equal or superior to that attained in otherwise less favored fabrics. But we can't just now; commercial considerations impede diffusion of knowledge for its own sweet sake. We must content ourselves to regard you as a consumer and technical thought-leader for other consumers.

Soon, in those capacities, you will be confronted with washable apparel and home furnishings proclaimed as being of *Estrel* fabric. This is a trade-mark signifying that our acetate fibre and *Eastofix Dyes* are its sole or dominant components. The implication is that in respect to color and press retention, shrinkage control, comfortable moisture balance, luxurious texture, wrinkle and soil resistance, ease of washing clean, and rapid drying after laundering, the combination is a good one.

If, perchance, you are in the trade and wonder what's in it for you, go ask Eastman Chemical Products, Inc., Kingsport, Tenn. (Subsidiary of Eastman Kodak Company).

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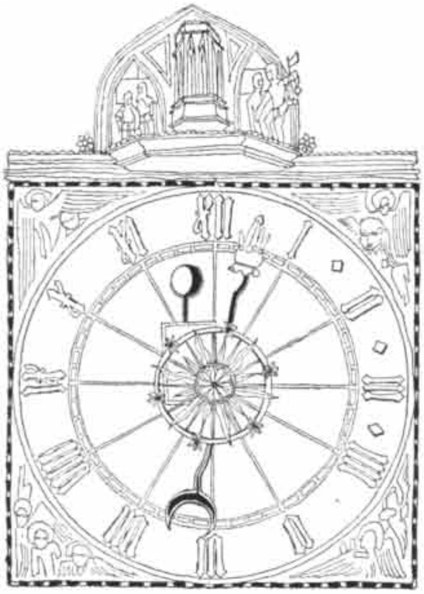
SCIENCE AND



Wanted: More Research

The Hoover Commission on Organization of the Executive Branch of the Government last month recommended to Congress an increase in Federal support of basic and medical research. The group, usually concerned about saving money, pronounced the current budget for basic research ($130 million) inadequate. "The safety, the increase of productivity, and the advancement of health in our nation must come from constantly increasing knowledge through fundamental research," said the Commission's report.

The Commission said that the Federal Government should give support to medical schools. It criticized the Department of Health, Education and Welfare for not requesting funds to carry out 723 medical research projects which had been approved.

The major portion of the report dealt with the Defense Department's research and development program. It found the military establishment not sufficiently "daring and imaginative" in developing new weapons and recommended that a standing committee of civilian scientists be appointed to keep an eye out for opportunities presented by new scientific discoveries. It also called for generally higher pay and an increase in the number of "high level" positions for scientists in the Defense Department.

Atomic Cooperation

Twenty-three countries have now entered into bilateral agreements with the U. S. for sharing nuclear information and material. In most cases the pacts provide that the foreign nation is to receive information on the design, construction and operation of research reactors and is to lease enough fissionable material from the AEC to fuel one. The material is to consist of a uranium mixture no richer than 20 per cent in U-235 and containing no more than 13.2 pounds of this fissionable isotope. Besides the reactor data, information on the use of radioactive isotopes in physical and biological research, medical therapy, agriculture and industry will be provided. With countries well advanced in nuclear technology, such as Canada and the United Kingdom, and with Belgium, the chief uranium supplier, the U. S. has agreed on more extensive cooperation.

Last month President Eisenhower announced that he will ask Congress to authorize the Government to build complete research reactors for other countries, with the U. S. paying half the cost, and to teach foreign technicians how to build and operate power reactors. The President also increased the total amount of U-235 to be made available to foreign nations from 220 to 440 pounds; this would provide enough for about 33 participating nations.

The countries which have concluded agreements are: Argentina, Belgium, Brazil, Canada, Chile, Nationalist China, Colombia, Denmark, Greece, Israel, Italy, Japan, Lebanon, the Netherlands, Pakistan, the Philippines, Portugal, Spain, Switzerland, Turkey, the United Kingdom, Uruguay and Venezuela.

Hush and Tush

Speculation about the "fission-fusion-fission" bomb ["Science and the Citizen," July] was indirectly confirmed last month by Atomic Energy Commissioner Willard F. Libby. This weapon is said to consist of a fission bomb which triggers a thermonuclear reaction which in turn causes ordinary uranium (238) to fission. In a speech at the University of Chicago, Libby mentioned "a nuclear explosion releasing 10 megatons of fission energy." The energy of the fission bombs in the pre-thermonuclear period was reckoned in tens of thousands of tons of TNT, not millions.

The magazine *Nucleonics* last month called attention to a Moscow radio broadcast which spoke of work by Soviet scientists to achieve controlled release of thermonuclear energy for power. Observing that such work is reported to be under way in the U. S. "in a special project at Princeton and the Livermore Laboratory," the magazine remarked that the U.S.S.R. announcement "seemingly does away with one high-level U. S. argument for not breathing a word about the subject."

Atlantic Telephone Cable

Far out in the North Atlantic Her Majesty's Telegraph Ship *Monarch* is inching its way eastward across the ocean, paying out the first cable that will carry telephone messages from America to Europe. Next summer the ship will repeat its journey, laying a second cable for westbound messages. The coaxial cables, each a ⅝-inch copper tube surrounding a single copper wire embedded in polyethylene, will stretch 2,372 miles over the uneven ocean bottom from Clarenville, Newfoundland, to Oban, Scotland. The pair of cables will carry 36 simultaneous conversations.

Telegraph cables have spanned the Atlantic for 89 years, but up to now transatlantic telephony has had to be by radio, with the "noise" to which radio is subject. Any long-distance telephone line requires amplifiers to boost the power along the way, and the problem has been the short life of these repeaters. For the Atlantic cables the Western Electric Company has designed a unit which it expects to operate without attention for at least 20 years. A stock amplifier of comparable fidelity might cost about $50. The cable repeaters come at $70,000 apiece. The cable requires one every 40 miles.

The project will cost $40 million and is a joint undertaking of the American Telephone and Telegraph Company and its Canadian subsidiary, the Eastern Telephone and Telegraph Company, and the British Post Office, which operates the telephones in England.

Electric Smog

British astronomers, when they are looking for stars, too often find nothing but fog and coal smoke. Therefore they have gone in intensively for radio astronomy, which is not troubled by atmospheric haze. Britain is now completing the world's biggest steerable radio telescope, with a parabolic antenna 250 feet in diameter, at the Jodrell Bank station of the University of Manchester.

But this monster's view also may be somewhat hazy. What soft coal is to the optical telescope, electrical machines and especially spark plugs are to the radio telescope. High-frequency radiation from nearby automobile ignition systems could completely overpower celestial radio signals at Jodrell Bank.

Just outside Jodrell Bank lies the town of Congleton, whose citizens have been planning some industrial and residential expansion near the observatory. The cars, trucks and buses attracted by such a development would outshine the entire Milky Way radio-wise. Last month all of England was watching a sharp battle between the town authorities and the anxious scientists at Jodrell Bank, who at latest accounts were still successfully blocking the town's building plans.

Observatory Saved

The Boyden Station observatory in South Africa, established by Harvard University in 1927 and all but given up by Harvard in 1953, has a new lease of life. Harvard, unable to support the Boyden Station alone, had agreed to keep it running for two years while other sponsors were sought. Now six observatories have undertaken to maintain it jointly: Armagh of North Ireland, Dunsink of the Irish Republic, Hamburg-Bergedorf of Germany, Stockholm of Sweden, Uccle of Belgium and Harvard.

For Better Science Teaching

The Carnegie Corporation of New York last month gave $300,000 to promote better science teaching in high schools. The grant went to the American Association for the Advancement of Science, which will use the money to set in motion its new Science Teaching Emergency Program ["Science and the Citizen," April]. Its main activities will be to recruit science teachers, seek better salaries for them, give cash awards to outstanding teachers and experiment with a plan whereby senior science teachers will help less experienced colleagues.

Polyethylene Process

A radically simplified method of making polyethylene has been developed in Germany. Until now pressures up to 30,000 pounds per square inch and temperatures around 400 degrees Fahrenheit have been required to combine ethylene molecules into a long-chain polymer. The German process makes polyethylene at atmospheric pressure and a temperature of 150 degrees.

A catalyst invented by Karl Ziegler of the Max Planck Institute for Coal Research makes the low-pressure synthesis possible. The nature of the catalyst has not been disclosed, but according to the journal *Industrial and Engineering Chemistry* it is probably triethylaluminum or a similar compound.

It is claimed that the Ziegler process will cut polyethylene production costs by half and plant investment by 80 per cent. Several U. S. companies are reported to hold licenses for the process. The Bakelite Company has announced that experimental quantities of the new material will be available soon from its West Virginia pilot plant.

Steroids for Surgery

A steroid anesthetic, the first of its type, has been developed by Charles Pfizer & Company. The substance, called Viadril, is given intravenously. Physicians who tested it at the University of California School of Medicine report that it produces a smoother, more even anesthesia than other intravenous agents, has less severe aftereffects, does not depress breathing or circulation as much, and relaxes the muscles. Thus it combines the effects of several other drugs.

The California anesthesiologists reported the most effective and safest way to use Viadril is to administer it in less than completely anesthetic doses in combination with nitrous oxide.

That steroids have an anesthetic effect was first noticed by the Canadian endocrinologist Hans Selye less than 20 years ago. G. D. Laubach of Pfizer recently synthesized Viadril, with the aid of S. Y. P'An and H. W. Rudel, from animal steroids converted to a form soluble in water.

Architecture of ACTH

Close on the heels of the complete unraveling of the first protein molecule, insulin ["The Insulin Molecule," by E. O. P. Thompson; SCIENTIFIC AMERICAN, May], another group has just determined the structure of a second protein hormone: ACTH. C. H. Li and his colleagues at the University of California have learned the positions of all the 39 amino acids that make up the straight-chain ACTH molecule, whose molecular weight is 4,500.

ACTH, manufactured in the anterior

part of the pituitary gland, acts on the cortex of the adrenal glands, stimulating them to produce various other biochemical regulators, including cortisone. In addition to this specific effect, ACTH appears to combine with other pituitary hormones in regulating a number of physiological processes. Now that the exact make-up is known, it should be possible to determine which parts of the molecule are responsible for which effects, and in time to synthesize the active fractions and the hormone itself.

Solving the puzzle of the ACTH molecule has been a five-year job. One of the major problems was to obtain enough pure hormone to work on. In the course of the entire research the California biochemists managed to extract one fourteenth of an ounce of crystalline ACTH from the glands of 360,000 sheep.

Working with Li were I. I. Geschwind, J. S. Dixon, R. D. Cole and I. D. Raacke. The study, which cost about $225,000, was supported by the Public Health Service, the Eli Lilly Laboratories and the Lasker Foundation.

Old Men

Two new rifts have been opened in the fog of prehistory. One affords a glimpse of the first tool-making creature, who lived possibly a million years ago. He is the manlike little fellow known as *Australopithecus prometheus*, whose bones are scattered generously through a number of caves in the Makapan Valley of South Africa. Raymond A. Dart of the University of Witwatersrand in Johannesburg, the first discoverer of Australopithecus, now reports that he has found two teeth of the man-ape in a deposit together with crudely chipped stone tools of the "pebble culture."

In the U. S. the oldest discovered evidence of human occupation has just been pushed back several thousand years. An excavating party from the Southwest Museum in Los Angeles has found traces of men who were in Nevada more than 23,800 years ago, according to radiocarbon analysis of charcoal from their site. Ruth D. Simpson, assistant curator of the museum, and several other anthropologists unearthed an ancient camp site where mammoth and camel bones lay in the ashes of a wood fire. The bones had been scraped and broken, obviously by tool-wielding men.

Infant Deaths

More U. S. babies now die in the first three days after birth than in the remaining 362 days of the first year. Unlike other mortality rates, those applying to the first week of life have been almost constant for several decades. Yet a substantial proportion of early deaths can be prevented simply by bringing obstetrical and pediatric procedures in hospitals up to accepted standards. So reports Herman N. Bundesen, Chicago physician and public health official, in *The Journal of the American Medical Association.*

A study of early infant deaths in Chicago hospitals showed that about 60 per cent result from breathing difficulties, 12 per cent from malformations, 10 per cent from birth injuries, 7 per cent from infections, 5 per cent from blood disorders (mostly Rh) and 6 per cent from other causes. Some of the faulty practices which contribute to infant deaths are: failure to start the infants' breathing after delivery and failure to resuscitate those who stop breathing; excessive use of anesthetics in premature deliveries, which depresses the breathing of the babies; failure to clear out clogged nose and throat passages; inadequate preparation for delivery of Rh-negative mothers; improper or delayed treatment of Rh babies; inadequate care of premature babies; inadequate medical supervision of interns and nurses. Poor record-keeping, which is typical of hospitals with high mortality rates, is itself a cause of death because it fails to disclose correctible abuses to hospital supervisors. All told, about 60 per cent of the early deaths involved some "preventable factors."

The Chicago Board of Health, of which Bundesen is president, is conducting a vigorous campaign against early infant mortality in the city's hospitals. Each death is analyzed to discover whether there were preventable factors. The Board confers frequently with hospital officials. An elaborate "alerter system" displays the status of each Chicago hospital in a colorful and graphic way on control panels with flashing signal lights, cards, colored tacks and the like.

As a result of the campaign the number of Chicago hospitals with death rates of 18 or more per 1,000 live births was reduced last year from 17 to 8. A university-connected hospital which had a rate of 27.8 deaths per 1,000 in 1953 reduced it to 10.2 in 1954.

A study just published by the New York Academy of Medicine shows that the Chicago figures are not unique. A committee of the Academy analyzed the records of 955 New York City infants who died within the first month after birth in 1950. One third of these deaths were considered preventable.

THE HONEYBEE

Studied by man for centuries, it is still the subject of delighted investigation. Its individual and social characteristics illuminate the differences and similarities between insects and higher animals

by Ronald Ribbands

Of more than two million kinds of insects in the world, the honeybee is the one we know most about and the one most useful to us. When we think of bees, we are apt to associate them first with honey and secondly, perhaps, with their sting. Actually it would be more appropriate to think of them first of all as the great pollinators, without whom many of the plants upon which mankind depends would disappear from the earth.

The food that bees take from plants is a small reward for their services, and the reciprocal relationship is advantageous to both the plants and the bees. The flowers have gradually acquired colors and scents which enable their insect allies to recognize them easily, as well as nectar and supplies of pollen with which to reward them. During the same time the bees have evolved into an increasingly efficient pollinating mechanism. The only insects that have become entirely specialized for flower pollination, bees are probably more effective in this work than all the other kinds of insects together.

Different kinds of flowers offer different attractions to insects. Some (*e.g.*, poppies) reward their visitors only with pollen; others (*e.g.*, clovers) provide them with both nectar and pollen; still others (*e.g.*, some basswoods and eucalypts) offer an abundance of nectar but no collectible surplus of pollen. Some flowers hide their nectar out of the reach of rain and useless insects, and their bee visitors have acquired longer tongues and more efficient mouth parts which enable them to obtain the hidden rewards. Bees have also evolved hairy coats to which the pollen clings readily. They leave a small proportion of the pollen grains on flowers as they flit from plant to plant, thus fertilizing them, but they carry most of the pollen home to feed their family.

The honeybee, by far the most numerous of all the bee species and well known all over the world, is the most successful bee by virtue of the fact that it has developed an efficient social system which enables it to live in colonies several hundred times as large as those of its nearest rivals. Among the benefits the size of its community bestows on the honeybee is the ability to maintain a high temperature within the colony and thus survive through the winter.

A primary requisite for the organization of any community is some effective method of communication. Human civilization grew from the development of language, writing and printing. And so it should not be surprising that honeybees have been found to possess effective means of communicating with one another.

As the honeybee's social life is the key to its success, it is no wonder that scientists have spent a great deal of time studying its community system. In doing so they have learned some things about social living in general—another debt we owe to this fascinating insect.

The Family

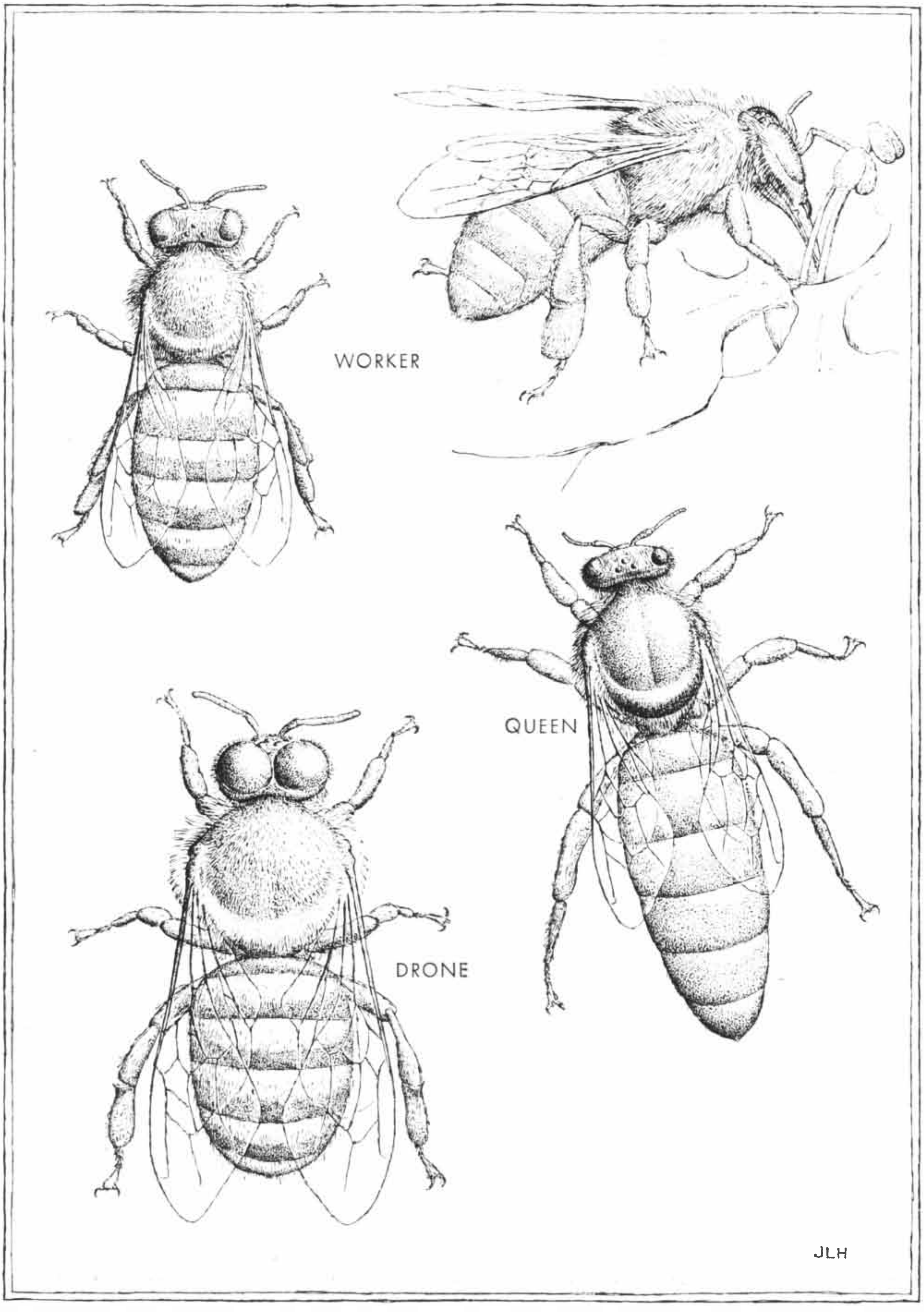
The social unit of the honeybee is the family. Each colony is headed by a big fertile female, or queen bee, which lays all the eggs for reproduction. Her family consists of up to 75,000 small infertile females, the worker bees, and several hundred male bees, the drones, which live only in summer.

The older worker bees supply the family with its food. They diligently forage for nectar and pollen, often carrying nearly their own weight of food supplies when they return to the hive. A bee may spend an hour or two on one collecting trip, during which it sometimes visits upward of 1,000 flowers.

The pollen provides protein for bodybuilding. The nectar contains sugars, which provide energy and raw material for the manufacture of beeswax. This wax, made in the bodies of the younger workers, is secreted in small scales which protrude from little pockets underneath the abdomen. When a scale is ready, the wax producer picks it off, chews it and fashions it into a thin ribbon of wax. From many thousands of these ribbons the workers construct the combs that provide the colony with a home. Each comb is a double layer of hexagonal cells, arranged back to back. It serves either to store honey or house the young brood. Worker bees are reared in small cells just big enough to contain the worker larva, and drones are raised in larger cells.

In summer, when worker bees are active, their average adult lifetime is only about a month, and so a great deal of brood has to be reared in order to maintain the large population of the honeybee colony. In fact, as it takes 21 days for a newly laid egg to develop into an adult worker bee, an expanding colony may contain more brood than adults.

The queen sometimes lays more than 2,000 eggs in a day—totaling four times her own body weight! Her stomach is smaller than that of a worker, but the worker bees feed her continually with bee milk, a nutritious predigested food. The younger workers form this milk from pollen and secrete it from modified salivary glands. Although the appetite of the queen is necessarily considerable, she takes only a small proportion of the available bee milk. Most of it is used to feed the developing brood, and probably some to feed the drones, which do not


WORKER
QUEEN
DRONE
JLH

feed themselves. A larva destined to be a worker is fed wholly on bee milk the first two days and then is "weaned" to a pap which contains large amounts of honey and some pollen.

A larva destined to become a queen is fed on bee milk throughout its larval life. It is this difference in feeding, coupled with the fact that the queen larva's food is not rationed, as it is to worker larvae, that produces the differences between a queen and a worker bee. When the colony needs a new queen, the workers construct a special large cell as her nursery. They pour bee milk into the cell as soon as the egg hatches, and the developing queen larva is always surrounded by more food than she can absorb. If a worker larva is transferred into a queen cell during the first two days of its larval life, it will become a queen; conversely, a queen larva transferred to a worker cell will become a worker. Thus the characteristics of a queen or worker are not inborn: they are determined by the quantity and quality of the food supplied from the third to fifth days of larval life. It is believed that in a three-day-old larva a plentiful supply of the nutritious bee milk causes the ovaries to develop rapidly and to produce a substance which, distributed through the body by way of the blood stream, produces queenly characteristics. This postulated substance would be a sex hormone similar to those which

QUEEN AND WORKERS bustle about the surface of a comb. The queen is the slightly larger bee above center. At the moment the photograph was made she deposited an egg in a cell of the comb. This photograph was made by Ben M. Knutson of Alamosa, Col.

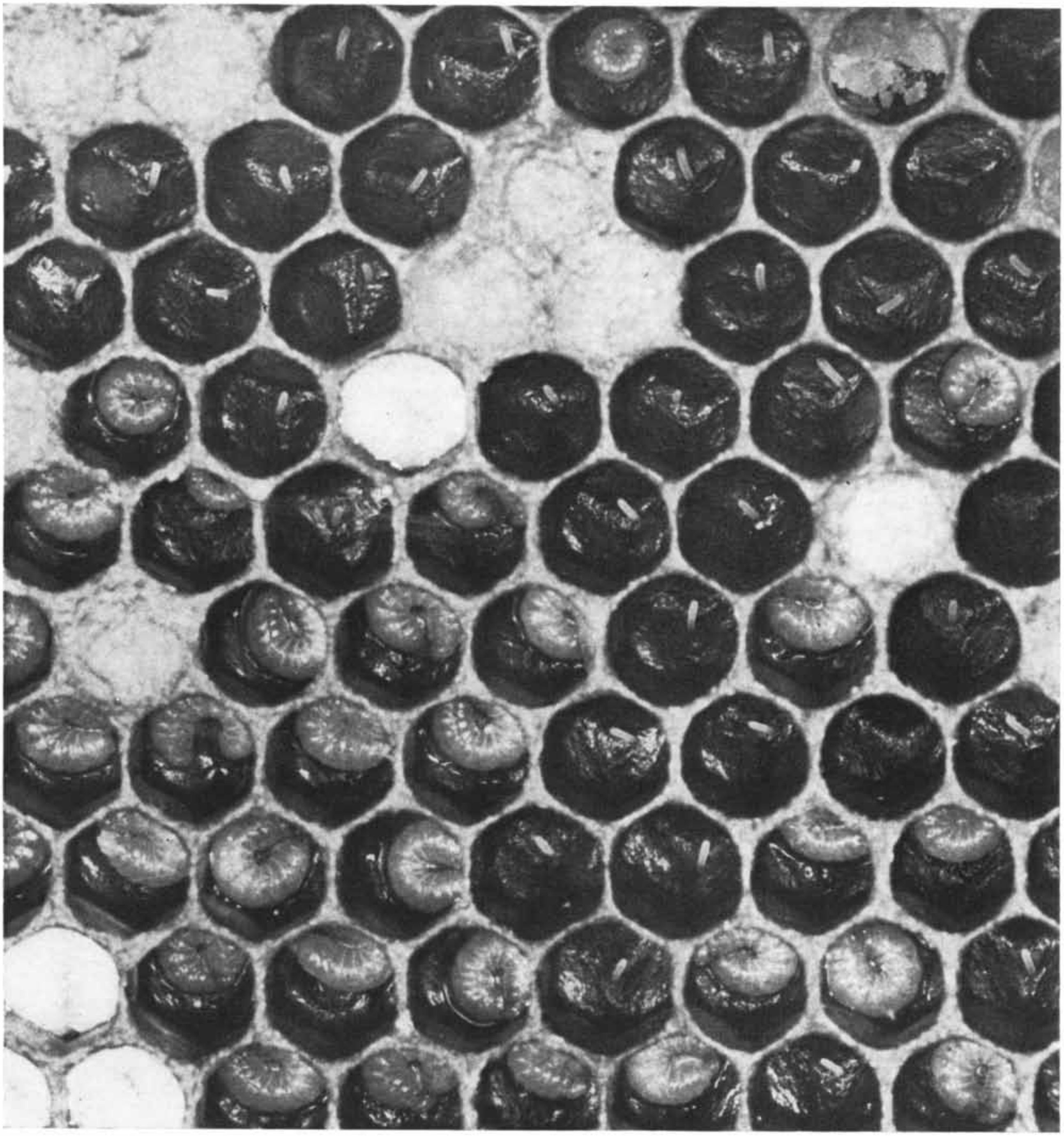
determine human secondary sexual characteristics. If the larva receives a less nutritious diet at this crucial time, its ovaries remain rudimentary and do not produce the hormone; therefore it becomes a worker.

More primitive social insects, such as wasps, produce no equivalent of bee milk. They feed their brood on undigested material chewed into pieces and mixed with saliva. It is easy to understand how the honeybee's feeding mechanism probably evolved: gradually the saliva itself became more and more nutritious and the pap had less and less food that was not predigested. The evolution of the bee milk made it possible for the honeybee community to increase its size and efficiency.

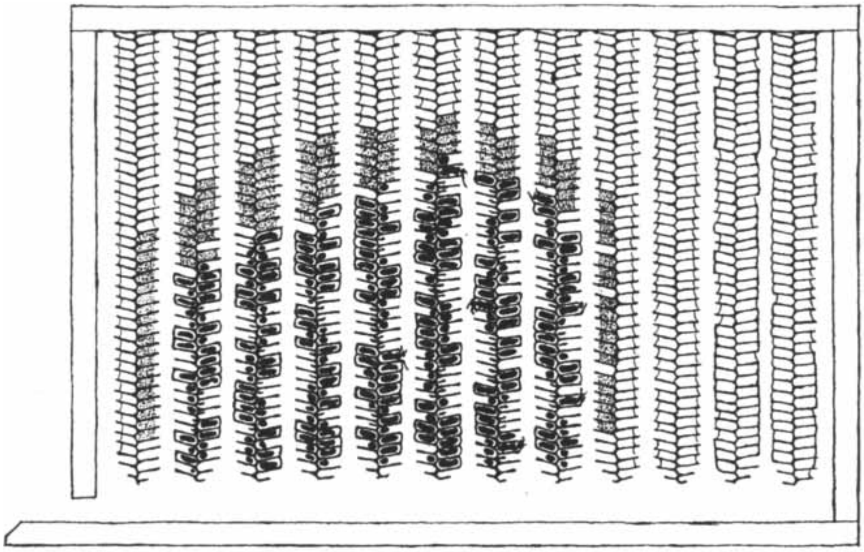
The Queen

A colony produces a new queen only when the reigning queen becomes defective because of age (she may live for several years), when it loses its queen or when the colony is about to multiply by swarming. If a beekeeper splits a colony into two, leaving one half queenless, the workers in the latter will enlarge the cell of one or more of the young worker larvae, supply an abundance of bee milk and convert the occupant into a replacement for their queen.

A colony which is preparing to swarm hangs wax cups in convenient positions



EGGS AND LARVAE are photographed in the cells of a comb. The larvae almost entirely fill their cells. The eggs are the small capsules at the bottom of some cells. The caps of beeswax placed atop the cells have been removed to make their contents visible.



BROOD OF BEES occupies only part of the comb structure within the hive. In this diagram the combs are seen from the edge. The black objects within some cells are eggs, larvae and pupae. The stippled cells are filled with pollen. Most of the open cells are filled with honey.

near the center of the brood-rearing area and encourages the queen to lay an egg in each cup. When an egg hatches, the workers extend the rim of the cup and supply its larva with an abundance of bee milk. The old queen now receives less and less food, lays fewer eggs and slims rapidly so that she becomes able to fly. Soon after the first new queen larva has pupated, a commotion commences among the worker bees in the colony. Many thousands of them, having gorged themselves with food, swarm out of their home, accompanied (but not led by) the old queen. They fly away to found a new colony elsewhere, leaving the developing new queen in her cell in the old colony. A few days afterward the new queen emerges from her cell. She immediately seeks out and stings to death any younger sister developing in other queen cells. If the colony is overcrowded, however, the workers remaining in the old colony may prevent her from doing this. In that event she will fly away with a crowd of workers in a second swarm, and a younger sister will succeed to the original colony.

When the established new queen of a colony is five to 10 days old, she begins to go off on lone flights for mating. Eventually she is found by a drone, which clasps her in the air, mates with her and promptly dies. The mated queen returns to her colony, is fed abundantly and settles down to her routine of egg production. In the mating act she has acquired sufficient sperm to last for her lifetime, and she cannot mate again after she has started to lay. Egg-laying is her only duty. The queen will not leave the hive again unless and until she goes off with a swarm a year or more later.

The process of replacing a failing queen is somewhat similar to the foregoing, except that the colony does not swarm, usually rears only one new queen larva, and the old queen remains with the colony. If the new queen does not kill her, she may live on for a time in amity with her tolerant successor.

The honeybee community has a remarkable ability to control its temperature. Retention of the heat liberated by the bees' consumption of food is regulated by the extent to which the members of the colony cluster together: the cluster loses heat more quickly if it expands, and conserves heat if it contracts. The bees arrange matters to maintain a constant temperature of 93 to 94 degrees Fahrenheit, the optimum for rapid development, during the breeding season. In winter they allow the nest temperature to fall if no brood is being reared, but they pack together tightly enough to ensure that it never falls below about 54 degrees F. Big colonies have maintained themselves at this temperature even when the outside temperature was 40 degrees below zero.

The Language

In recent years the study of communication among bees and of the complex activities achieved through this communication has yielded results of unending fascination [see "The Language of the Bees," by August Krogh; Scientific American, August, 1948; and "More on the Language of the Bees," by Hans Kalmus; July, 1953]. We now have

WORKERS ATTACK a foreign bee which attempted to enter their hive. The members of each colony have a distinctive odor that enables them to detect members of other colonies.

further information to supplement the earlier accounts.

One of the most important agencies by which the bees communicate is the food they share. As Karl von Frisch, the leading investigator of bee communication, has shown, when bee foragers come home to the hive laden with food they show their hive mates the direction and location of the food sources by means of dances on the comb. And they tell their fellow workers not only where to look but what to look for. A nectar gatherer distributes samples of the nectar to other workers; the odor of the nectar identifies the flowers from which it was collected, so that the new foragers search for flowers with that particular scent. Similarly the bees identify the source of pollen by scenting it when their antennae touch the pollen attached to the hind legs of the collector. The honeybee has come to depend greatly on this effective message system and teamwork. Nearly all the foragers in a colony are recruited to a crop by companions: only a few find a crop without help.

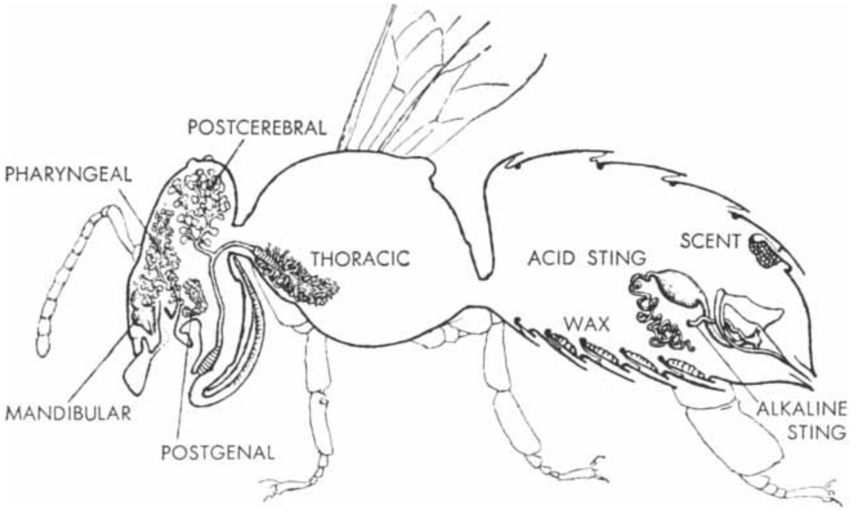
The Workers

The workers in a honeybee colony exhibit an amazing ability to carry out, at precisely the right time and with an efficient division of labor, the various jobs that need to be done: brood rearing, wax production, comb building, nectar ripening, foraging, defense. Any worker bee is potentially able to perform any of these tasks. The older ones tend to specialize in foraging for food and defending the hive, leaving work inside the hive to others. But Martin Lindauer, who watched marked individuals for long periods, found that the younger workers turned to whatever needed doing at the moment: on any one day they might cover the whole range of duties concerned with handling and processing food. I have postulated that the members of the community are sensitive to surpluses or deficits of individual ingredients in the food they share, so that they adjust their duties until the right proportions of them are employed on each task according to the colony needs at a given time. Lindauer recently observed that when a colony needed much water, foragers brought in load after load; when the need diminished and they could not dispose of their water load quickly, they stopped going out for more.

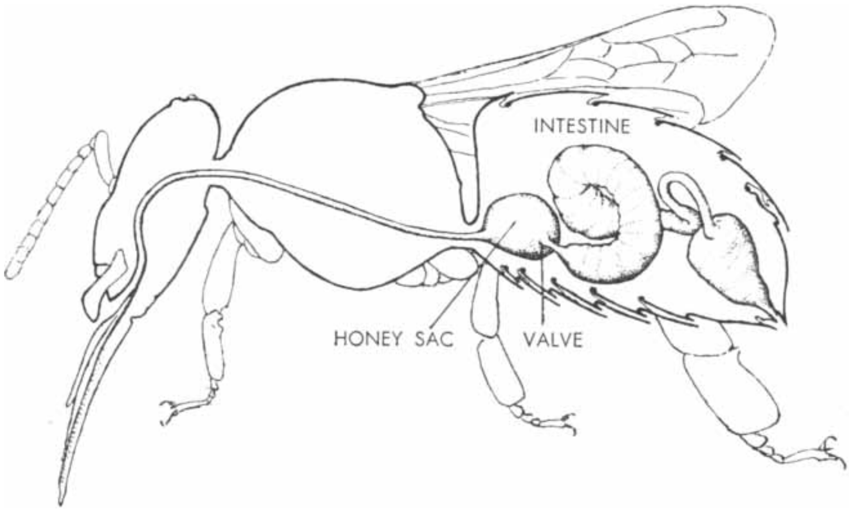
The bees pass on information by means of secretions from their bodies. For instance, C. G. Butler has shown that worker bees lick a substance from the body of the queen and convey it from bee to bee in the food they share. Thus the thousands of bees in a colony are apprised of the presence of their queen although only 10 or 20 of them are in direct contact with her at any one time. Any deficiency in the amount of the queen substance is quickly detected by the colony as a whole, and causes it to take steps to rear another queen. If a queen is removed from her colony, the workers become aware of her absence within an hour or two and excitedly search for her.

More than 50 years ago the beekeeper Frank Sladen recorded that he had noticed a distinct odor arising from a swarm of bees which he was putting into a hive. Further investigation showed that the bees were emitting the odor from a scent organ at the tip of the abdomen, which was raised in the air. Recently Hans Kalmus and I, working together at the Rothamsted Experimental Station, were able to prove that all the bees of any one colony produce a distinctive scent which is different from that of the bees of other colonies. This scent is derived from the colony's specific food supply. When portions of a colony are separated and fed different foods, each portion has a different scent, as determined from the bees' behavior;

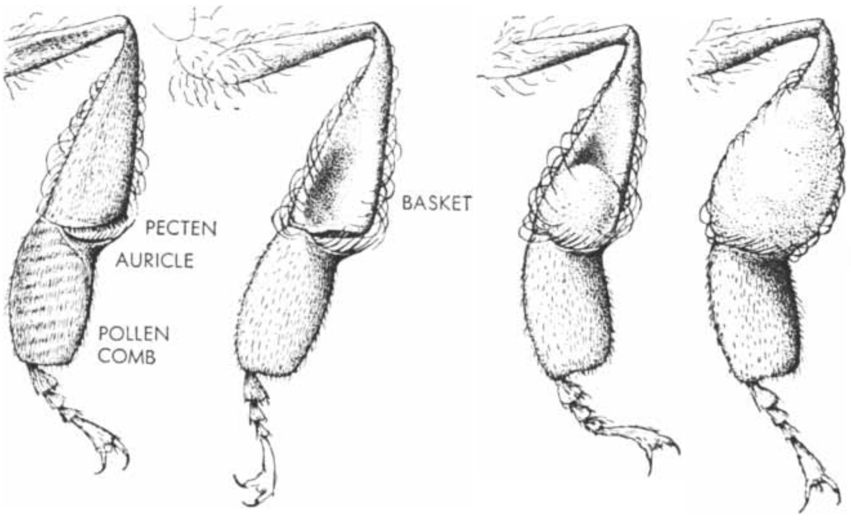
WORKERS SHARE FOOD in the hive. The foraging bee (*right*) opens its mandibles, revealing a droplet of nectar on its tongue. The receiving bee stretches out its proboscis and sips the nectar. Food sharing gives rise to the distinctive odor of each bee colony.



GLANDS of a worker are shown in cross section. The pharyngeal glands secrete bee milk. The wax glands secrete wax in tiny scales which the bee chews and fashions into a ribbon.



ALIMENTARY CANAL of a worker is similarly shown. Honey is regurgitated from the honey sac. When the bee is hungry, it opens the valve between the honey sac and intestine.



HIND LEG of a worker is shown from the inside (*drawing at left*) and the outside (*three drawings at right*). The pollen basket is progressively filled. It is emptied by the pecten.

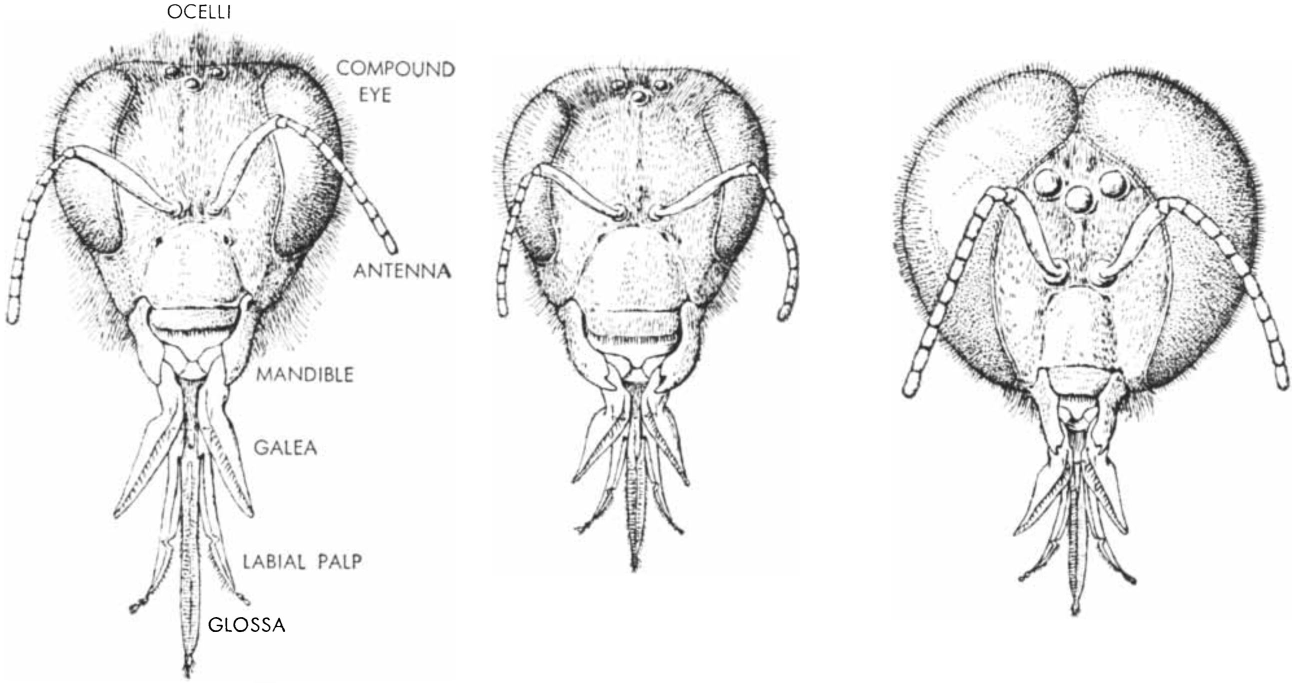
the odors are not distinguishable by the human nose. The only plausible explanation of these facts is that usually all the bees in a colony share the same food and develop the same odor. Experiments with radioactive sugar confirmed that the mixture of foods taken into a colony is shared fairly evenly among all the bees. After a marked bee collected a radioactive sugar syrup offered to it, the "labeled" sugar was later traced by means of a Geiger counter to its hive mates. I have found that one stomachful of radioactive sugar may be shared out among almost all the bees in a large colony. Different colonies of honeybees, even in the same apiary, usually gather quite different proportions of the various kinds of nectar and pollen available. Thus the different colonies generally acquire different odors.

Each colony's distinctive odor enables it to detect strangers and to defend itself against attempts at robbery. A foreign bee that tries to enter the colony to steal honey is attacked and thrown out. The evolution of food sharing therefore has been a means of improving defense for the bee community. This indirect use of food sharing is perhaps the most surprising of all its functions.

The Individual

We must remember that a bee is an individual as well as a member of a community. Because honeybees are easily kept and studied, their anatomy and physiology have been extensively investigated. As insects, honeybees are not exceptional, either in sensual acuteness or in behavior. Like many insects, they can perceive color differences but are blind to red and can see ultraviolet, which is invisible to human eyes. This means that two flowers which appear of the same color to us may appear different to the bee, and *vice versa*; it has been estimated that about 30 per cent of all conspicuous flowers have strong ultraviolet hues.

A honeybee's capacity to distinguish patterns is much inferior to ours. Its limitations are illustrated on page 60: Mathilde Hertz found that bees could not be trained to distinguish the patterns within either the upper or the lower row from one another. However, in two respects their eyesight is superior to our own. They respond to movements more readily than we do, and their eyes have the valuable ability to appreciate the plane of polarization of light [see "Polarized Light and Animal Navigation," by Talbot H. Waterman; SCIENTIFIC AMERI-



HEADS of a worker (*left*), queen (*middle*) and drone (*right*) are compared. The mouth parts of the worker are highly developed for food gathering. The eyes of the drone are enlarged for seeking the queen. The three ocelli are simple eyes whose function is unknown.

CAN, July]. This ability was discovered accidentally, after experiments had shown that the bee's dance told the direction of a source of food. Von Frisch noticed that the form of the dance changed from hour to hour during the day, and that this change could be related to the change in the direction of the sun. The bees were able to determine the sun's direction even when it was obscured by clouds. Further experiments then demonstrated that the honeybee's eyes were sensitive to the polarization of sunlight in the sky.

The honeybee is able to compensate for the sun's movement across the sky because it has an accurate perception of time. It can be trained to visit a feeding dish at precisely the time of day when food is provided. This ability is bound up with its metabolism: if a bee is fed quinine, which slows down its vital processes, it arrives at the dish late, and if its food contains salicylic acid, which speeds things up, it comes too soon.

The appreciation of time is geared to the appreciation of direction of the sun. This gearing, presumably automatic, allows a honeybee which has learned to collect syrup from a dish at a point, say, 300 yards south of its hive, to find the dish when the sun is either in the west or the east. It will locate the dish the following morning even if both the hive and the dish have been moved overnight to a new locality, so long as the dish is placed at a point 300 yards south of the hive.

A bee's sense of hearing is extremely limited. There is some evidence that it responds to a piping noise which the queen bee can make by forcing air through her abdominal spiracles. Sound vibrations transmitted through solids, rather than air, are of prime importance to the honeybee. It perceives mainly through its antennae, and it is able to translate the rapid waggling of the abdomen in the signaling dance into the distance to be traveled to the food source. Probably mechanical vibrations, transmitted through the comb, are perceived by sense organs on the bees' legs.

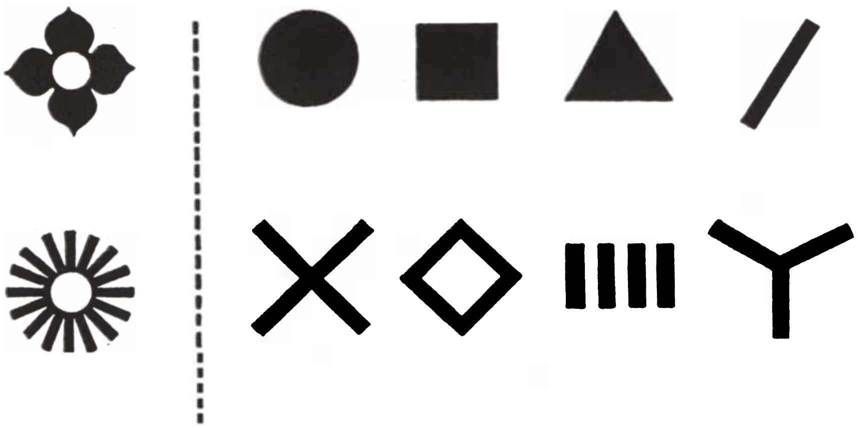
We do not know how bees measure the distance they have flown, but there is no doubt they are able to do so. When a dancing bee has flown with the wind or downhill, its dance often understates the distance; hence it has been suggested that the bee measures distance in terms of energy used. In my view it is more likely that the antennae are displaced in some way during flight, and that sense cells in them register the length of time during which this displacement occurred.

The honeybee's sense of smell resides in the seven outermost joints of its antennae. This sense is far more acute than ours: some of my experiments indicate that a bee has about 50 to 100 times greater capacity for recognizing airborne scents than we do. It can detect very slight differences between mixtures of scents which we could not appreciate. Moreover, the insect's antennae possess an inestimable advantage over the human nose in that its sense organs touch the object, thus coming in contact with a much greater concentration of scented particles than is wafted on the air.

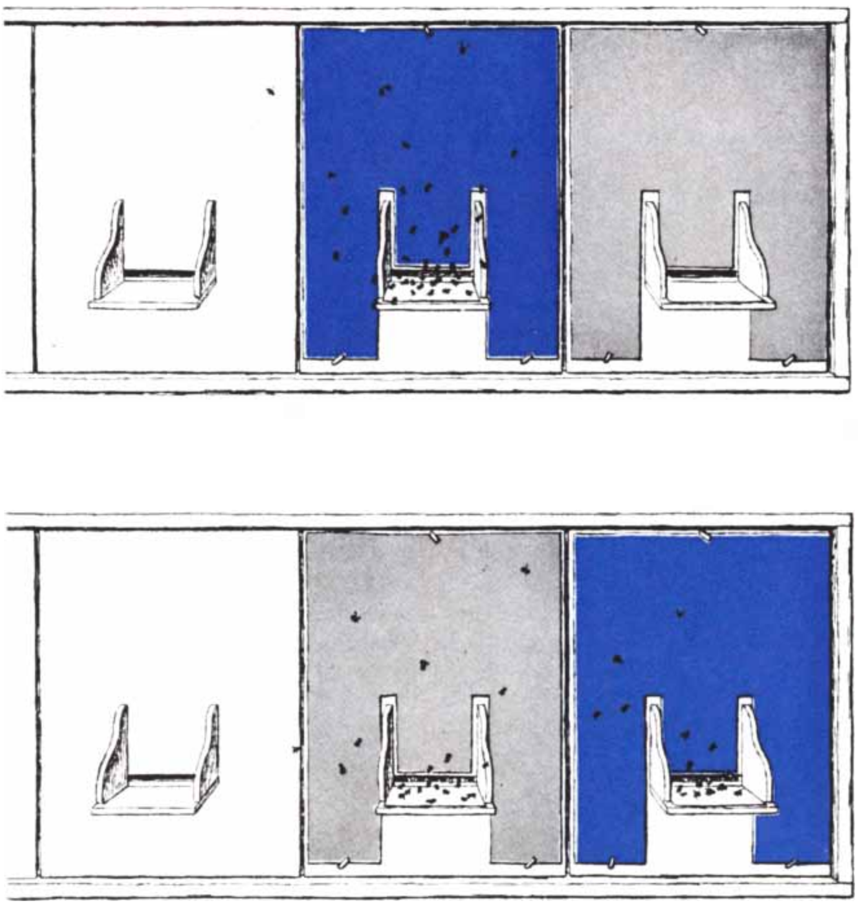
I found that a foraging honeybee could be trained to pick out, from a group of identical glass tubes, one on which it had landed momentarily a short time previously, presumably because the tube was marked with the bee's scent. This ability probably is useful in various ways: for example, foraging bees may detect in this way flowers which have been visited by other bees and thus avoid wasting time on blossoms depleted of their nectar and pollen. Recent experiments suggest that bees can distinguish scents from different parts of a flower.

Navigation

Because a bee's senses are so different from ours, it is not easy to discover how the insect uses its senses to perform its everyday functions. How, for instance, do flying honeybees find their way about? They often forage up to a mile away from the hive, and sometimes as far as five miles. In locating food and the hive itself they use a complex combination of senses: vision, smell, perception



PATTERN VISION of bees is limited. They can easily distinguish between the two shapes to the left of the dotted line. They cannot distinguish between the shapes in the top row to the right of the dotted line, nor between the shapes in the bottom row to the right of the line. They can distinguish between the shapes in the top row and those in the bottom row.



COLOR VISION of bees helps them find their way. These drawings illustrate an experiment of Karl von Frisch. The top drawing shows three beehives. The hive in the center is occupied; the hives at the left and right are unoccupied. The hive at the left is painted white; the hive in the middle is covered with a blue metal sheet; the hive at the right is covered with a yellow metal sheet (*symbolized by gray tone*). The reverse side of the blue metal sheet is yellow; the reverse side of the yellow metal sheet is blue. The bottom drawing shows the three beehives with the blue and yellow sheets turned around. Some of the bees now go to the blue, but empty, hive, indicating that they use color to find their way back to the colony.

of distance and of direction in relation to the sun. Apparently the senses used for guidance vary according to the circumstances. Two experiments illustrate this. Albrecht Bethe caught a number of bees outside their hive, removed the antennae of half of them and put all back into the hive. Then he moved the hive a few feet away from its old position. When the normal bees left the hive on expeditions, they generally returned erroneously to the old hive site. But most of the bees without antennae flew back correctly to the hive in its new position! Bethe concluded that the antennaless bees used their eyesight, while the normal ones depended more on another faculty for guidance. In the other experiment Ernst Wolf found that, when first learning a route, bees might guide themselves by visible landmarks, but that they soon learned to ignore the landmarks and to steer course in relation to the direction of the sun until they were near their objective; then they called scent and sight into play to help identify the object itself. Moreover, there can be no doubt that the senses other than vision are all-important in enabling bees to learn from their comrades what crops to look for and the whereabouts of those crops.

The simplicity of the insect nervous system puts important restrictions upon a honeybee's behavior. It seems to have a one-track mind, usually unable to comprehend more than one thing at a time. An example of this single-mindedness has been described by Elizabeth Opfinger. Employing an ingenious color-changing device, she demonstrated that a honeybee does not notice the color of a flower while feeding on it or upon leaving it; the bee identifies the color of the flower only during the very short time when it is approaching to alight.

Such single-mindedness suggests that the complex associations made in a bee's learning and conveyed in its communicative dance are entirely automatic. Quite different messages, traveling through the same nerve channels, become associated with one another. In this way the angle of the dance on the comb and the tempo of the waggle come to indicate the direction and distance, respectively, of the food.

In this brief survey of the honeybee I have tried to bring out how the individual and social characteristics of bees throw light on both the differences and the similarities between insects and higher forms of life. Nature has built us very differently, but we all live in the same world and are subject to the same physical and chemical laws.

The Speed of Light

Methods for measuring this universal constant have become more and more precise. Yet today there is considerable doubt about the true value. It may even have changed in the past 20 years

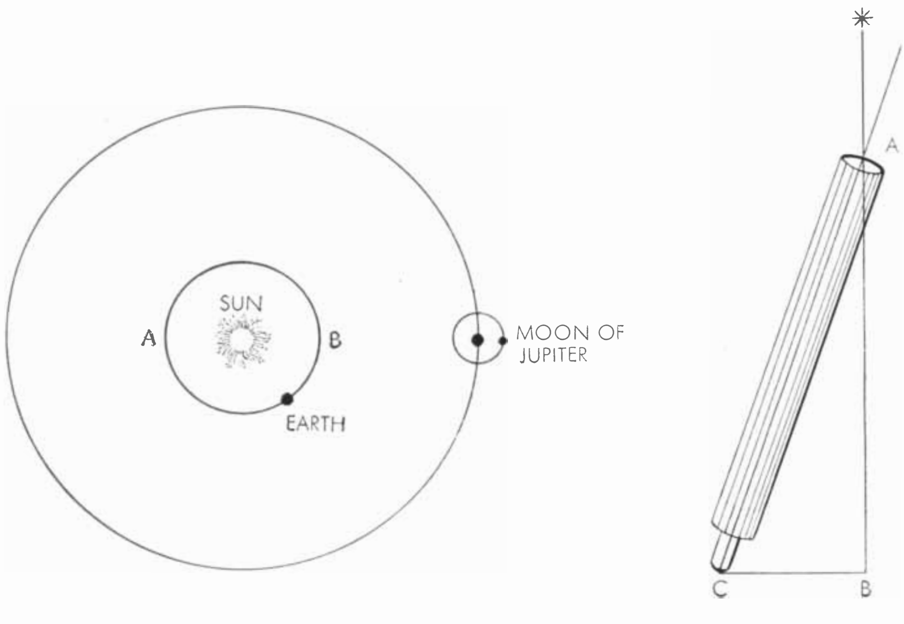
by J. H. Rush

Among the fundamental constants of nature, the velocity of light has a special allure and a particularly interesting history. It is the highest possible velocity at which anything can travel—the ultimate speed limit of the universe. It is one of the few clues we have to the properties of empty space. It was the foundation upon which James Clerk Maxwell built his universal theory of electricity and magnetism, and Albert Einstein his theory of relativity. It is the key quantity in the fateful equation $E=mc^2$, in which the *c* is the conventional symbol for the velocity of light. And not the least of its points of interest is that for three centuries it has stimulated scientists to great heights of ingenuity to measure it with ever more meticulous precision.

Why have physicists labored so hard to refine the accuracy? What difference can it make to know the speed of light within a fraction of a mile per second? The first motive for their efforts is simply the thirst for precise knowledge, particularly about fundamental matters; another decimal place means more knowledge. But in addition there is always the possibility that more accurate measurement will turn up a significant discrepancy. The precise measurement of atomic weights led to the discovery of isotopes of the elements. As it happens, the most recent measurements of the velocity of light have produced an unexpected disagreement which raises a question as to whether the speed of light is actually constant!

Galileo was one of the first to try to measure the velocity of light. Using a hand-operated shutter, he sent flashes from a lantern to an assistant on a nearby hill, who signaled back. They succeeded only in demonstrating that the speed of light must be fantastically great. But clues from astronomy before long gave proof that the speed was finite. In the 1670s a Dane named Ole Roemer observed that Jupiter's eclipses of its moons were seen at later times than expected when the earth was farther away from Jupiter, and he deduced from this that the delay represented the travel time of light; he calculated that light took about 1,000 seconds to cross the diameter of the earth's orbit around the sun. Fifty years later an English astronomer, James Bradley, found another way to make an astronomical measurement of the velocity of light when he discovered that the position of every star shifts according to the earth's motion in its orbit. It is apparently displaced in the direction of the earth's movement (the phenomenon is called aberration). The motion causes the light to seem to come at a different angle, just as, when you drive a car south in a cross-wind blowing from due west, the resultant wind impact on the car is from the southwest. The faster you drive, the farther the wind seems to swing toward the south. Bradley recognized that the speed of light could be calculated roughly from the angle of aberration (about 20.5 seconds of arc) and the known speed of the earth's motion (about 18 miles per second).

Accurate measurement of the velocity of light did not really begin until 1849. In that year the French physicist Hippolyte-Louis Fizeau performed his classic experiment with a toothed wheel and a mirror. The method employed in Fizeau's device, and in most of those de-



ASTRONOMICAL METHODS gave crude values. Roemer measured the time required for light from Jupiter to cross the earth's orbit from B to A (*left*). Bradley measured apparent star displacements, which depend on relative speeds of the earth and the starlight (*right*).

veloped during the following century, was essentially the one attempted by Galileo: namely, the timing of the travel of a pulse of light over a measured distance. Fizeau chopped the light beam into short pulses simply by rotating his toothed wheel in front of the light; the notches let bursts of light through. Each pulse traveled to a distant mirror and was reflected back to the rotating wheel. If it arrived when a notch was in its path, Fizeau could see the returning light as a bright spot in an eyepiece; if it encountered a tooth on its return, the blocking of the light dimmed the eyepiece. By rotating the wheel at such a speed that it advanced just half a space between the release of the pulse and its return, so that the light was blocked by the tooth next to the notch, Fizeau was able to determine the time of the pulse's travel to the mirror and back. This interval, divided into the distance of the round trip, gave the velocity. Fizeau's measurement for the velocity of light was 313,300 kilometers per second. It was far from accurate, but his idea paved the way for more precise instruments.

Léon Foucault, who had worked with Fizeau, soon thought of an improvement. A weakness of the Fizeau device was that the observer had to make a subjective (physiological) judgment as to when the returning beam reached maximum or minimum brightness in the eyepiece. Foucault astutely substituted a rotating mirror for the toothed wheel. When the light pulse returned from the distant mirror, the turning mirror deflected it, the angle of deflection being determined by the angle through which the mirror had turned while the pulse was traveling to the second mirror and back. Thus the observer did not have to judge brightness but merely read the displacement of the beam on a scale in the eyepiece. With this instrument Foucault measured the velocity of light to be 298,000 kilometers per second—much closer to the mark than Fizeau's value.

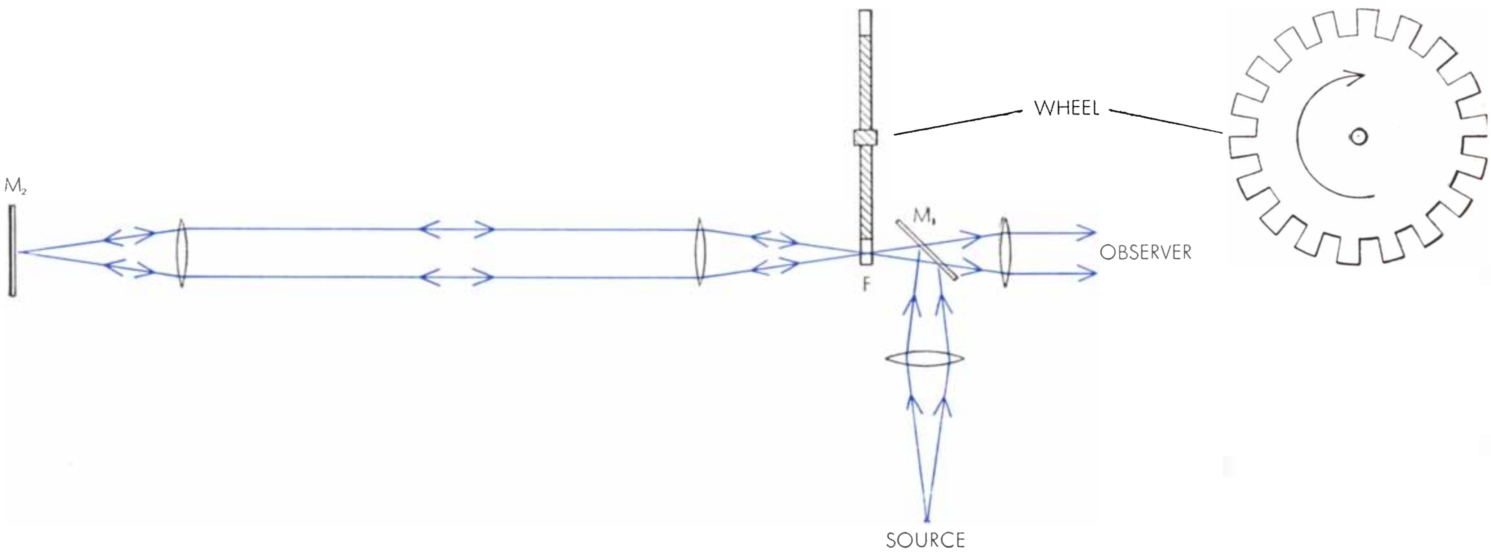
In 1923 Albert A. Michelson applied the Foucault method on a spectacular scale. He stationed his rotating mirror on Mount Wilson in Southern California and set up the fixed mirror on Mount San Antonio, 22 miles away. To measure the distance between the two mirrors precisely, the U. S. Coast and Geodetic Survey laid out a primary base line in the San Gabriel valley, probably the most accurately measured line ever marked on the earth's surface. Then they triangulated from the base line to Michelson's mirror sites on the mountains, and determined the distance between them to about one part in a million, or one inch in the 22 miles.

With this enormous base line and certain detailed improvements he had made in the apparatus, Michelson was in a more favorable position than any previous experimenter had been to obtain a really precise and convincing value for c. During the next three years he labored with the apparatus. Finally he announced a result of 299,796 kilometers per second—a figure which comes very close to measurements today.

To standardize the results, the measurements of c always have to be corrected to vacuum, for the speed of light is affected by the density of air. The optical properties of air are so accurately known that this correction is usually as precise as the velocity measurements themselves. But Michelson, who had been much troubled by haze and turbulence in the long path he had employed, decided to build a vacuum path. With Francis G. Pease of the Mount Wilson Observatory and Fred Pearson of the University of Chicago, he set out to construct a vacuum tube a mile long. On a ranch in Southern California they laid down a continuous tube of corrugated steel culvert pipe on a carefully surveyed base line. They enclosed the necessary mirrors and other apparatus, closed the ends, sealed the joints and evacuated the air with powerful vacuum pumps. By reflecting the light back and forth several times, they made its total path 10 miles long.

Michelson died in 1931, soon after beginning the experiment. His collaborators worked on through the next two years, varying and refining the experimental conditions. Their final result for c, based on thousands of individual readings, was 299,774 kilometers per second—22 kilometers less than the mountain-top measurements.

The vacuum-tube installation was wrecked by the Long Beach earthquake of 1933, and it is not likely that a Foucault mirror ever will be used seriously



FIZEAU'S METHOD timed a light beam over a path of 10.72 miles. In his apparatus light from an arc source was reflected from semitransparent mirror M_1 toward the toothed edge of a rotating wheel. Bursts of illumination passing through the wheel were reflected from mirror M_2 5.36 miles away. The return beam, if not stopped by a rotating tooth, passed through M_1 to the eye of the observer.

again. New techniques for measuring c—compact, inexpensive, incredibly precise—now make the heroic efforts of the past appear quaint and futile. One of the new methods, however, is a 20th-century child of the Fizeau-Foucault contrivance. The most important limitation of the mechanical light chopper was the restriction on the speed of the rotating element, which made the long light paths necessary. The 20th-century version, first used by A. Karolus and O. Mittelstaedt of Germany, overcame the difficulty by adopting an electronic light chopper. It delivered several million light flashes per second and made feasible a light path only 136 feet long. The chopper is a Kerr cell: a glass cell containing a liquid (usually nitrobenzene) which in an electric field can transform an entering beam of plane-polarized light into a "circularly polarized" beam, where the electric field of the light wave rotates around the axis of the beam, corkscrewing its way through space. When the electric field is off, the plane-polarized beam passes through the cell unaltered and can be blocked by a crossed polarizer. But when the voltage is applied to make the light circularly polarized, the emerging beam is not completely blocked by the perpendicular polarizer, and part of the light gets through. Thus the turning on and off of the voltage can alternately pass and block the light. A high-frequency electrical oscillator such as is used in a radio transmitter can be made to charge the cell millions of times per second, chopping a light beam into pulses only a few feet long. The frequency of the oscillator voltage, which is equivalent to the time interval between light pulses, can be measured to an accuracy of one part in 10 million.

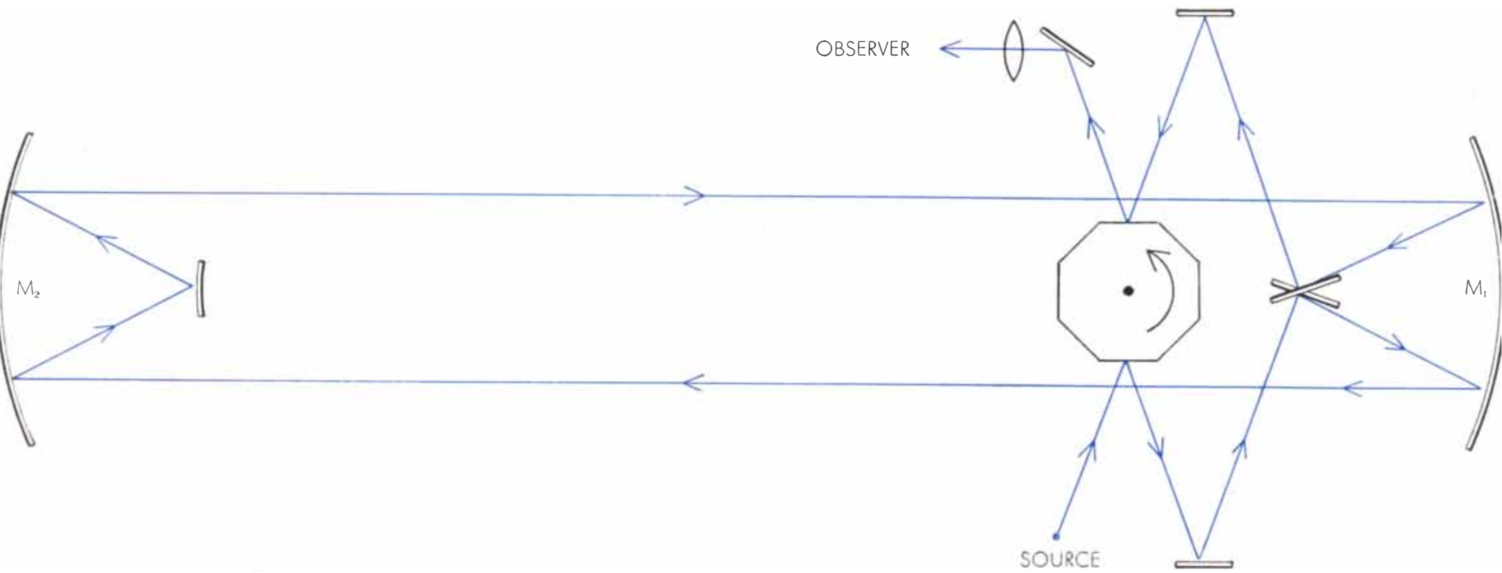
Just before World War II, A. Huettel in Germany and W. C. Anderson at Harvard University, using Kerr cells with refinements of technique, measured the speed of light at 299,768 and 299,776 kilometers per second, respectively, which agreed well with the value obtained with Michelson's mile-long vacuum tube.

Meanwhile two fundamentally new approaches had developed. The first was a consequence of Maxwell's epochal discovery that the ratio of the units in the two systems for measuring electrical quantities (electrostatic and electromagnetic) yielded the velocity of light [see "James Clerk Maxwell," by James R. Newman; SCIENTIFIC AMERICAN, June]. The numerical value of such a ratio can be determined by measurement. In 1906 E. B. Rosa and N. E. Dorsey of the National Bureau of Standards measured it very precisely and computed the speed of light as 299,781 kilometers per second.

The other new approach was first used by Jean Mercier of France in 1923. Up to that time all the experimenters who had measured the speed of light directly, beginning with Fizeau, had done so by determining the time it took light to travel a fixed distance. Mercier measured it by determining the rate at which it passed a fixed point. If a train of cars passes you at a constant speed, you can measure the speed by counting the number of cars that pass per minute and multiplying by the length of a car, provided the cars are all the same length. Just so the velocity of a train of light waves is simply the length of one wave multiplied by the number of waves that pass per second. Of course the frequency of visible light waves is so high—about 600 thousand billion per second—that it is impracticable to measure them. But radio waves travel at the same speed, and they are more manageable. Mercier generated standing electromagnetic waves on wires, analogous to the vibrating segments of a piano or a violin string, and measured the distance from one voltage crest to another; this, with the known frequency of the waves, gave the velocity. He got a value of 299,782 kilometers per second.

By 1940 the various precision measurements of c appeared to be converging satisfactorily toward one value. R. T. Birge, analyzing the experiments, concluded that the velocity of light was very close to 299,776 kilometers per second.

After the hiatus of World War II there came not only new techniques of measurement but also a curious jump in the measured velocity. In 1951 Commander Carl I. Aslakson of the U. S. Coast and Geodetic Survey, testing the radar system called Shoran as a surveying method, found that its measurement of distances was consistently shorter than



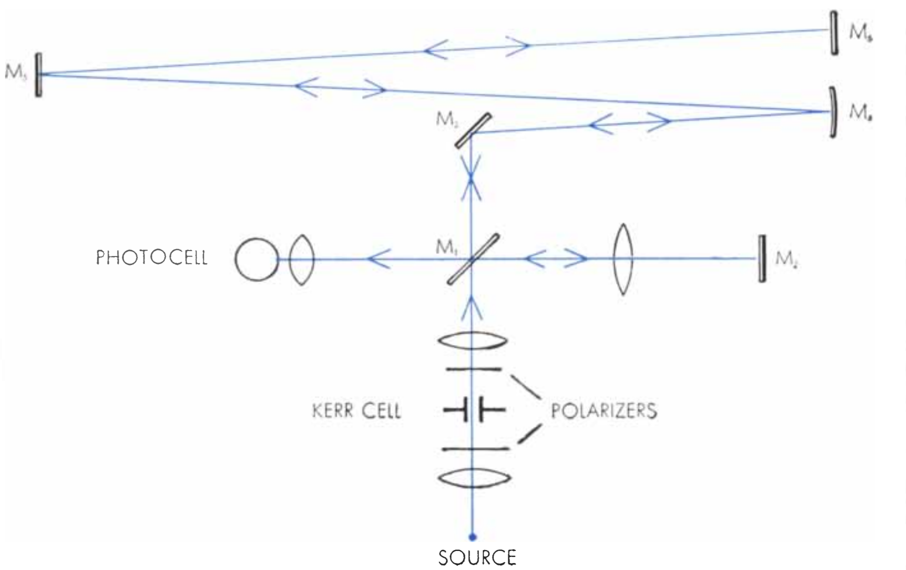
MICHELSON'S APPARATUS was based on a rapidly rotating octagonal mirror. Light traveled from one face of this mirror to M_1, thence to the distant mirror M_2 and back to the opposite side of the octagon. If this had made an eighth of a revolution, there would be a face in position to send the beam to the observer. The rotor, about an inch in diameter, was placed 30 feet away from M_1.

that by conventional triangulation. His crews had used the value of 299,776 kilometers per second for the velocity of the radar pulse. Analysis showed that the radar distances would agree with the triangulation distances if the velocity was assumed to be 299,794.2! Meanwhile Erik Bergstrand in Sweden, employing light and an electronic chopper for a surveying system, also found that it required about the same value for *c*—299,792.7.

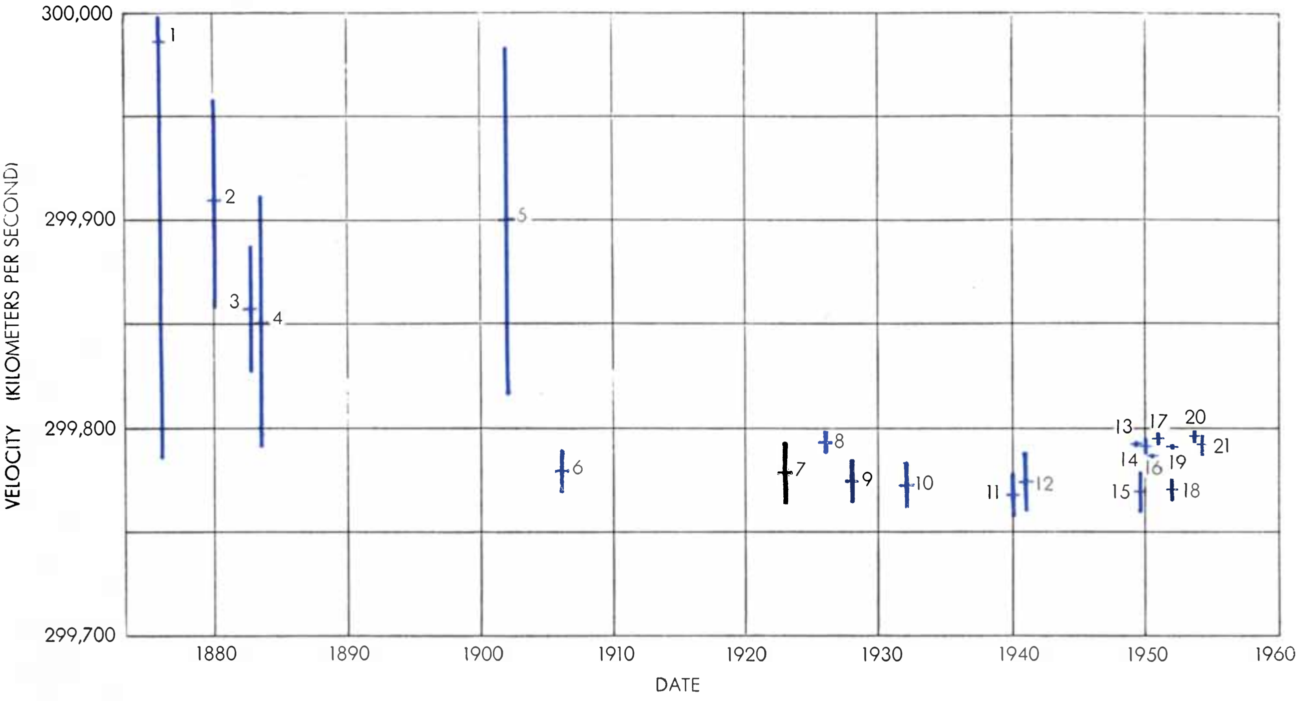
In 1948 L. Essen and A. C. Gordon-Smith of the National Physical Laboratory in Great Britain announced the results of a series of measurements on a microwave cavity resonator. This experiment is similar in principle to Mercier's standing waves on wires, but the measuring tool is more nearly analogous to an organ pipe than to a violin string. The wavelength of the radio waves can be calculated from the measured size of the particular cavity in which they will "tune" or resonate. The resulting values for *c* are among the most precise ever recorded. Essen and Gordon-Smith obtained the value 299,792 kilometers per second, which Essen soon afterward refined to 299,792.5. Similar values were obtained by Kees Bol and the late W. W. Hansen at Stanford University and by K. D. Froome in Britain and E. F. Florman in the U. S., using variations of Mercier's experiment.

Recently two experiments have been made with a method of appealing directness and ingenuity, suggested by A. E. Douglas of Ottawa. It employs equipment which raises the frequencies of microwaves many octaves—up to 10 or 100 billion oscillations per second—so that it can "tune in" on the rotational frequencies of certain molecules. By a complex process it is possible to measure the wavelength of the waves generated by the rotation of a given molecule, and the product of this wavelength and the microwave frequency that tunes to it is the velocity of light. Such a determination of *c* was carried out by D. H. Rank and associates at Pennsylvania State College with the molecule cyanogen (CN), and they derived the value 299,776 kilometers per second. Early in 1954 E. K. Plyler of the National Bureau of Standards reported a similar experiment with carbon monoxide which gave the result 299,792.

So we have three fairly distinct sets of values for *c* from the long series of measurements over the past century [*see chart on next page*]. The first group consists of determinations made before 1905. While they were crude and widely divergent by present standards, it seems remarkable that all these values were higher than the later ones. The second group of results, at a new level of precision, begins with Rosa and Dorsey's measurement in 1906 and ends with Anderson's in 1941. These experiments, made by four very different methods, yielded remarkably consistent values, with the single exception of Michelson's mountain-top measurement. Omitting that one result, which may be considered



ANDERSON'S METHOD uses half-silvered mirror M_1 to split intermittent beam from Kerr cell into two parts. Both go to the photocell, one directly via M_2, the other after a 560-foot trip via remaining mirrors. Photocell output indicates time to traverse extra path.



NUMBER	DATE	EXPERIMENTER	METHOD		VELOCITY
1	1876	CORNU	TOOTHED WHEEL	L/T	299,990 ±200
2	1880	MICHELSON	ROTATING MIRROR	L/T	299,910 ±50
3	1883	NEWCOMB	ROTATING MIRROR	L/T	299,860 ±30
4	1883	MICHELSON	ROTATING MIRROR	L/T	299,853 ±60
5	1902	PERROTIN	TOOTHED WHEEL	L/T	299,901 ±84
6	1906	ROSA AND DORSEY	MAXWELL'S BRIDGE	ESU/EMU	299,781 ±10
7	1923	MERCIER	WAVES ON WIRES	λν	299,782 ±15
8	1926	MICHELSON	ROTATING MIRROR	L/T	299,796 ±4
9	1928	KAROLUS AND MITTELSTAEDT	KERR CELL	L/T	299,778 ±10
10	1932	MICHELSON, PEASE AND PEARSON	ROTATING MIRROR	L/T	299,774 ±11
11	1940	HUETTEL	KERR CELL	L/T	299,768 ±10
12	1941	ANDERSON	KERR CELL	L/T	299,776 ±14
13	1950	BERGSTRAND	ELECTRONIC CHOPPER	L/T	299,792.7 ±.25
14	1950	ESSEN	MICROWAVE CAVITY	λν	299,792.5 ±3
15	1950	HOUSTOUN	VIBRATING CRYSTAL	L/T	299,775 ±9
16	1950	BOL AND HANSEN	MICROWAVE CAVITY	λν	299,789.3 ±.4
17	1951	ASLAKSON	SHORAN RADAR	L/T	299,794.2 ±1.9
18	1952	RANK, RUTH AND VANDER SLUIS	MOLECULAR SPECTRA	λν	299,776 ±7
19	1952	FROOME	MICROWAVE INTERFEROMETER	λν	299,792.6 ±.7
20	1954	FLORMAN	RADIO INTERFEROMETER	λν	299,795 ±3.1
21	1954	PLYLER	MOLECULAR SPECTRA	λν	299,792 ±6

PRINCIPAL ATTEMPTS to measure the speed of light are summarized in the chart and table above. Vertical lines on the chart represent the range of error in each measurement, with the most probable value indicated by the short cross mark. The column to the left of the list of velocities on the chart refers to the theory underlying each method. L/T means that the experimenter essentially measured a distance and a time and found the velocity by dividing the two. ESU/EMU refers to the ratio of electrostatic to electromagnetic units. The expression "lambda nu" indicates that the wavelength (lambda) and the frequency (nu) of some electromagnetic radiation were each measured experimentally and that these values were multiplied together to give the waves' velocity.

particularly subject to error because of the difficulty of evaluating the atmospheric effects, the mean for the rest of this group is 299,776.5 kilometers per second.

Group three comprises the nine values of c reported since the war. Again these are characterized by a new order of precision—to a fraction of a kilometer per second in some cases. Seven of the nine results are very consistent and yield a weighted mean of 299,791.8 kilometers per second, or 186,282 miles per second. Curiously, the other two agree remarkably well with each other and with the mean of group two. However, one of them, representing the work of Rank and his associates on molecular spectra, was superseded by Plyler's presumably more reliable result for the same experiment, and his figure agrees with the other seven. The one remaining anomalous value is that obtained by R. A. Houstoun at Glasgow in 1950. He used a vibrating quartz crystal as the chopper and a short path in the laboratory, and his measurement for c was 299,775 kilometers per second.

Here, then, we have a puzzling situation. The prewar and postwar measurements, separated by a decade, show a consistent difference of about 16 kilometers per second. Can it be that the velocity of light is not constant, that it actually increased by about 16 kilometers in the 10-year interval? That a difference of this magnitude between the two self-consistent groups of measurements occurred by chance is not very probable. Yet there are compelling reasons for holding to the belief that c must be a constant.

For instance, if the velocity of light is not constant, then its wavelength or frequency or both must change with time. No systematic changes in wavelengths have been observed. The possibility that frequencies may vary with time is not excluded by any direct evidence we have so far. Perhaps this issue will be settled soon by certain new techniques for comparison of atomic or molecular oscillation frequencies with the rotation of the earth, the independent standard to which those frequencies are referred.

The techniques for measuring the velocity of light have become so precise that the next 10 years should answer the question whether c actually varies as much as the recent measurements indicate. A great deal hangs on the answer. In science the results that do not fit the theory are always the most exciting and important. They lead to discovery.

PLACEBOS

They are inactive pills or injections that are designed to look like the real thing. Physicians use them for their psychological effect on the patient or as controls to test new pharmaceuticals

by Louis Lasagna

Webster's Unabridged Dictionary gives at least four separate definitions of placebo. It is an ancient word which has had a multiplicity of meanings in English over the centuries. In Latin it means "I shall please." Possibly its oldest use in English, said to date back at least to the 13th century, is as the name of the vespers for the dead in the Roman Catholic service, which begins with a recitation from the 114th Psalm in the Vulgate: *Placebo Domino in regione vivorum. . . .* A second ancient use of the word was to signify an act of sycophancy or a practitioner of that art—in short, a toady. Chaucer gave the name Placebo to a character of this type. Less harshly, the word has been used by some writers to mean something intended to soothe or conciliate. Thus Sir Walter Scott wrote: "With this placebo [soothing sentiment] she concluded her note."

Such are the antecedents of the word which today is commonly known only in its medical sense: to describe an inactive, harmless pill or injection which is given solely for its psychological effect on the patient. The modern medical definition was first presented in 1811 in *Hooper's Medical Dictionary:* "placebo—an epithet given to any medicine adopted more to please than to benefit the patient." The definition seems to connote a servile and unscientific surrender by the physician to the demand or desire of his patient for medication. It would be pointless and dishonest to deny this aspect of the practice of medicine. A medical practitioner is often faced with the need for marking time. He may be awaiting the results of diagnostic tests, or be baffled by a patient's complaints, or know the correct diagnosis but lack effective treatment. However, society has never completely divorced the physician from the witch doctor, and for many patients the notion that the doctor lacks omniscience or omnipotence in his domain is extremely disturbing. In such situations, when the patient expects or demands some tangible evidence of therapeutic intent or capability, it is usually simplest (and wisest) for all concerned to prescribe a harmless pill or liquid.

Certain primitive maneuvers are necessary to insure the success of this pharmaceutical charade. First, the patient must be kept unaware of the deceit. A good start is usually made with the writing of the prescription. The well-known illegibility of these scripts frequently makes it impossible for a curious patient even to guess at the nature of the medicament. If the handwriting is legible, it is still likely to be in Latin. To guard against the possibility that the patient will ask the pharmacist about the contents of the prescription, physicians are well advised to steer clear of milk sugar or other well-known ingredients. There are available various vile-tasting and vividly colored tinctures which not only are impressive in physical properties but bear names calculated to inspire confidence in the erudition of the prescriber. Names such as ammoniated tincture of valerian can safely be revealed to the patient without upsetting the psychological applecart.

Some authorities consider the color of the preparation very important. Colorless capsules are presumed to be unimpressive. One writer advises yellow, orange or brown; another prefers pink, blue or a mottled design. Similarly, tasteless placebos are considered inferior to bitter or highly flavored ones. It is believed that an extraordinarily large pill impresses by its size, an exceptionally small one by its "potency." An injection is thought to be more effective than something taken by mouth: presumably the presence of the nurse or physician necessary for the injection is an important component of the psychological effect. I hasten to point out that most of these "principles" of the art of the placebo are based not on any systematic investigation of the facts but on impressions. Almost no controlled studies of them have been made.

In addition to treatment, placebos have a second and in some ways more important use. They are often valuable for controlled tests of new drugs or therapeutic procedures: witness last year's field tests of the Salk poliomyelitis vaccine. If a standard medicament of proved potency is available, the new drug and the standard can be compared to determine whether the new compound is inferior, equal or superior to the old. If no such standard is available, a placebo should serve as the control. Such a test makes it possible to decide whether "cures" are due to the new drug itself rather than to suggestion or to spontaneous changes in the course of the disease. The enthusiastic hope of the patient and the investigator for successful results from the drug must be bridled, or at least allowed to distribute itself equally between the drug and the placebo. They are given in identical appearing capsules or fluids, and neither the subjects nor the investigators know who got what until the end of the experiment. Sometimes the new drug proves to be more potent than the placebo, sometimes precisely as potent, and sometimes less potent (or at least more toxic).

With regard to the effect of a placebo, obviously the patient is at least as important as the placebo itself. Some people react to placebos while others do not;

the former have come to be designated by physicians as "placebo reactors." What makes a person a reactor? Almost all physicians agree that one necessary trait is "suggestibility" (which is easier to name than to define or measure), but on the rest of the description they are less united. Some incline to the view that complaining, whining (usually female) patients are most likely to respond dramatically to placebos. Other physicians believe that the dependent, passive patient, eager to rely on authority figures, is the reactor type.

Considering how profound an effect placebos may have on reactors, producing impressive recoveries or "toxic" reactions, it is surprising how little study has been given to identifying the characteristics of such persons. It would seem highly desirable to be able to pick out the reactors in a group of patients, whether one is attempting to increase the efficiency of treatment or planning a research experiment. For example, a population composed almost exclusively of placebo reactors would be useless for distinguishing between a highly potent drug and an inactive one, since all medications would produce relief.

During some research on pain-relieving drugs at the Massachusetts General Hospital, J. M. Von Felsinger, Frederick Mosteller, Henry K. Beecher and I decided to compare the responses of a group of 162 patients to morphine and to a placebo. All the patients had just been operated on and were suffering pain from the operation. They were given an injection whenever they requested something for pain, and before and after each injection they were asked to tell the location and severity of the pain and the degree of relief obtained. Sometimes the patient got morphine, sometimes only a placebo.

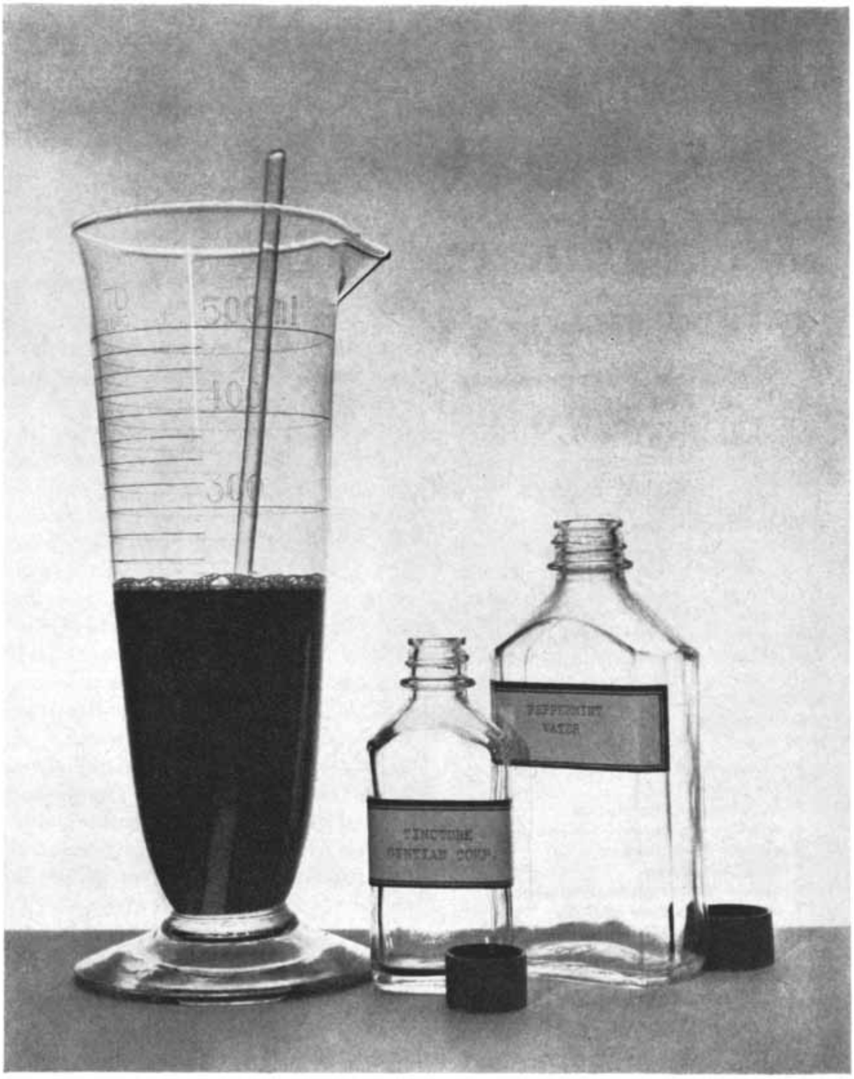
More than half of the patients reacted to the placebo. Of those who received only one injection of placebo, 42 per cent reported significant relief of pain after the injection. Of those who were given placebo injections more than once, 69 per cent got significant relief on at least one occasion. A few reported that their pain disappeared completely. The patients who responded to placebos also were more apt to be relieved by morphine than were the nonreactors.

The effect of the placebo (as of morphine) apparently depended in part on the severity of the pain, for we found that the patients who made the most requests for medication obtained relief only a small proportion of the time.

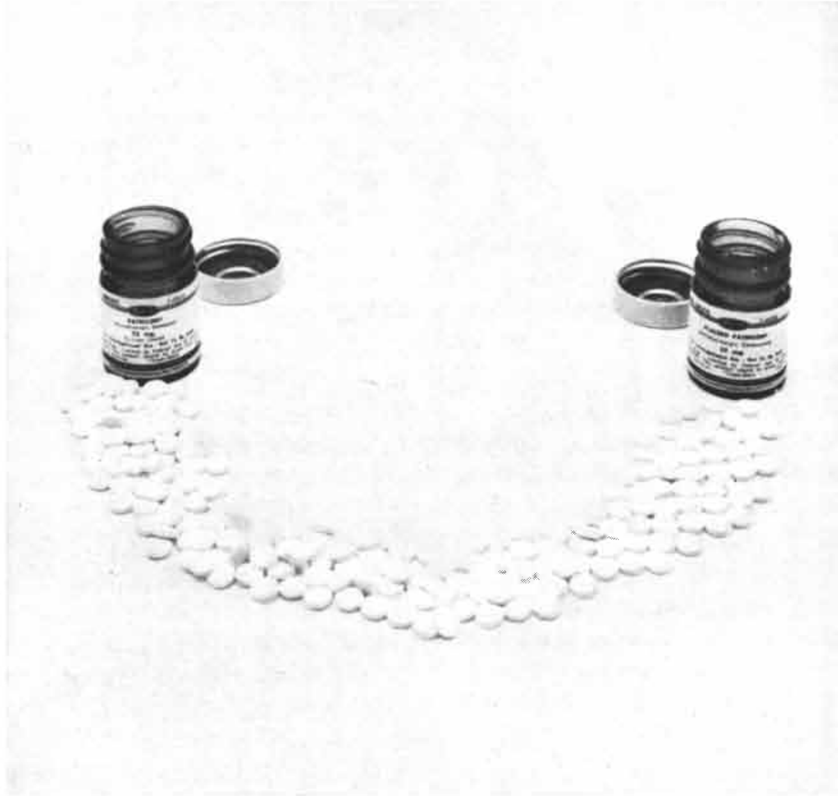
There was an interesting inconsistency of response to the placebo on the part of most of the reactors. In the group that received two or more doses of placebo, 31 per cent were nonreactors: they never obtained relief. The extreme reactors, who always got relief from pain, made up 14 per cent of the group. The remaining 55 per cent sometimes obtained relief, sometimes not. Thus if one had ventured to predict, on the basis of the first response, whether an individual would get relief from subsequent doses of the placebo, he would have been wrong more often than right.

The point of major interest in the study, however, was whether the reactors as a group could be differentiated psychologically from the nonreactors. It quickly appeared that neither sex nor age was significant: women were no more likely to respond to a placebo than men, and the reactors were distributed over the whole age range from 35 to 64. For detailed study of possible psychological differences we selected two groups of individuals—one consisting of those who had reacted to the placebo every time and the other of those who had invariably failed to react. The total number of subjects in this study was 27.

Two clinical psychologists, who were kept unaware of the identity of the reactors, interviewed and tested all these individuals shortly before they were sent home from the hospital. One psychologist interviewed primarily the female subjects, another the male. As already indicated, sex and age were of no help in distinguishing the reactors from the nonreactors. Nor was intelligence: the average I.Q. scores of both groups were identical. Certain differences did appear,



PRESCRIPTION PLACEBO is a liquid preparation of the old style, containing peppermint water and tincture of gentian compound. Pharmacists seldom receive prescriptions of this kind today. The physician tends to prescribe actual but relatively inactive medicines.



TEST PLACEBO tablets are spread out from their bottle at the right. Extending from the bottle at the left are tablets of Pathilon, a drug that has been found useful in the treatment of peptic ulcer. The tablets of drug and placebo are identical in appearance. Here, however, the bottle containing the placebo is labeled. In an actual test it would not be.

however, in the interview data and in responses to the Rorschach ink-blot personality test.

On the average the reactors had two years less formal education than the nonreactors. The reactors were happier about their hospital experience: they all thought the hospital care "wonderful" and they tended to minimize the amount of postoperative discomfort they had suffered, while the nonreactors seemed to have had a much harder time, though as a group they had not had more serious operations. The reactors were described by the nurses as more cooperative but slightly more concerned about themselves than the nonreactors. The reactors seemed in general less critical individuals, frequently answering "everyone" to the question, "What sort of people do you like best?" Two thirds of the reactors said they had a tendency to develop somatic symptoms (diarrhea, headache, nervous stomach) under stress. The female reactors gave a history of severe menstrual pains, and of taking medication for such symptoms, more frequently than did the female nonreactors. The reactors were more often characterized as "weepers" and "talkers" by the interviewing psychologists. Every placebo reactor in this group was a veritable pillar of the church, attending services with regularity and being greatly interested and active in church affairs.

The Rorschach tests indicated the reactors to be more anxious and less hostile than the nonreactors. Judging from the pattern of their responses, they seemed more dependent on outside stimulation than on their own mental processes, which tended to be immature. While more anxious and dependent than the nonreactors, the reactors were also more volatile and outwardly oriented, and thus might be more likely to "drain off" their anxiety and tension. Their volubility during the interviews could be an expression of this sort of mechanism.

The most striking feature of the reactors' performance on the ink-blot test was the great frequency of responses related to the pelvic and abdominal viscera. The nature of their responses would be considered definitely pathological were it not that a certain amount of preoccupation with one's bodily processes may be expected in a hospital setting. The reactor group, in any case, produced many more such responses than did the nonreactor group.

So it appears to be possible to differentiate reactors as a group from nonreactors if we take only the extremes—those consistently one or the other. However, it must be remembered that there is no "average" reactor (just as there is no "average" man), and hence it is difficult to predict whether any particular individual will be a reactor. What the study does seem to support is the notion that there are personality characteristics and habits of mind which predispose a person to respond to a placebo. The psychological predisposition to respond is probably present in varying degrees in most of us. Some persons are very likely to respond positively in a wide variety of situations; others will almost never respond positively whatever the situation; most people probably lie somewhere between these extremes.

Placebos have been reported effective in relieving not only postoperative pain but also a host of other complaints. Henry K. Beecher, of the Anesthesia Laboratory at the Harvard Medical School, recently summarized the results of many investigators who found that placebos gave relief to about one third of the patients suffering discomforts ranging from headache to angina pectoris. A particularly striking example of the effect of suggestion in medicine is the response of some patients to the mere fact that a surgeon has operated on them. There are cases on record where surgeons, after cutting open patients with advanced rheumatic heart disease, have decided for one reason or another not to operate on the valves of the heart as they had intended. Nevertheless some of these patients, apparently under the impression that the operation was successfully carried out, have shown dramatic improvement afterward!

Doubtless several factors combine to determine how a patient will react to a placebo in any given situation: the patient's own personality, the type and severity of his illness, the attitude of the physician, the environment and so on. There is no *a priori* reason to assume that the variables which were effective in the situation we investigated (pain after operation) will also be effective in another. Only further investigation can elucidate this interesting point.

It is hoped that the pioneer studies here described will stimulate other investigators to enrich our knowledge of the placebo and its actions. As the medical profession well knows, there is an element of suggestion in everything the doctor prescribes. It behooves us to know as much as possible about this problem—one as old as medicine itself.

THE HOMING SALMON

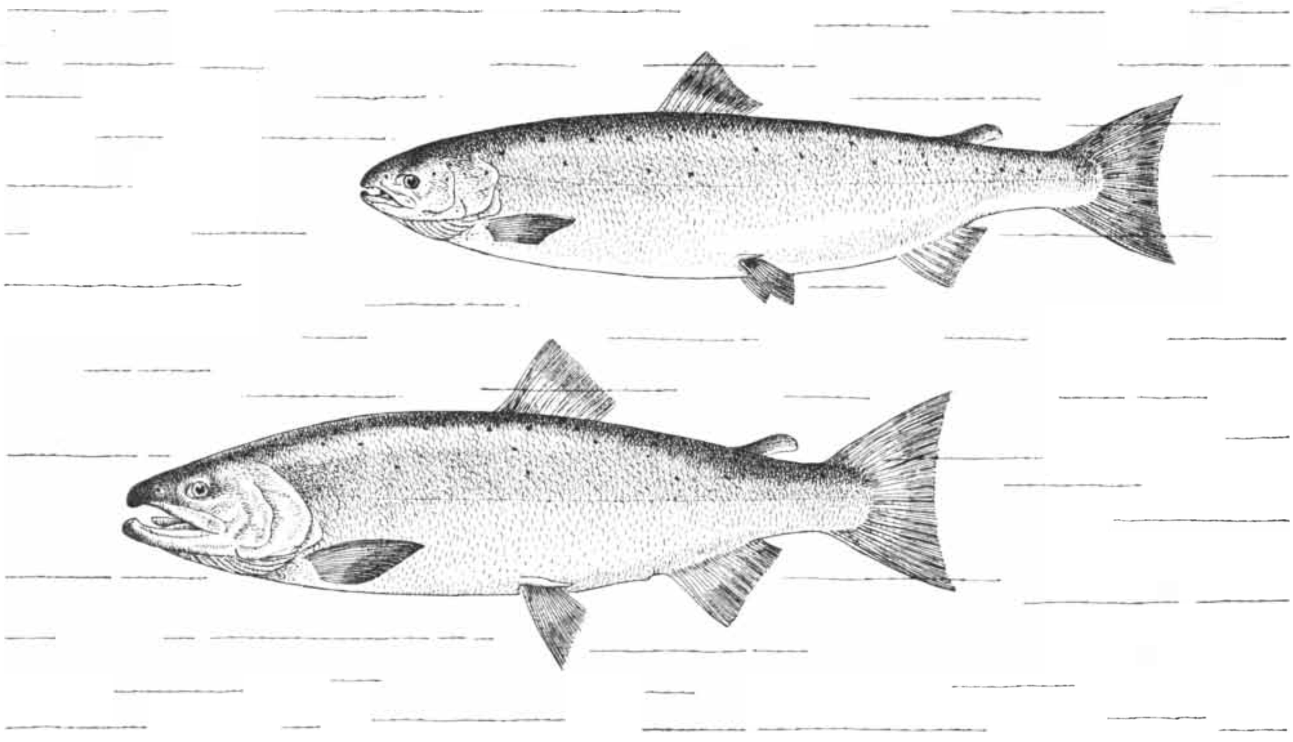
How do salmon find their way back to the waters of their birth? Recent experiments in the laboratory and in the field indicate that they do so by means of a remarkably refined sense of smell

by Arthur D. Hasler and James A. Larsen

A learned naturalist once remarked that among the many riddles of nature, not the least mysterious is the migration of fishes. The homing of salmon is a particularly dramatic example. The Chinook salmon of the U. S. Northwest is born in a small stream, migrates downriver to the Pacific Ocean as a young smolt and, after living in the sea for as long as five years, swims back unerringly to the stream of its birth to spawn. Its determination to return to its birthplace is legendary. No one who has seen a 100-pound Chinook salmon fling itself into the air again and again until it is exhausted in a vain effort to surmount a waterfall can fail to marvel at the strength of the instinct that draws the salmon upriver to the stream where it was born.

How do salmon remember their birthplace, and how do they find their way back, sometimes from 800 or 900 miles away? This enigma, which has fascinated naturalists for many years, is the subject of the research to be reported here. The question has an economic as well as a scientific interest, because new dams which stand in the salmon's way have cut heavily into salmon fishing along the Pacific Coast. Before long nearly every stream of any appreciable size in the West will be blocked by dams. It is true that the dams have fish lifts and ladders designed to help salmon to hurdle them. Unfortunately, and for reasons which are different for nearly every dam so far designed, salmon are lost in tremendous numbers.

There are six common species of salmon. One, called the Atlantic salmon, is of the same genus as the steelhead trout. These two fish go to sea and come back upstream to spawn year after year. The other five salmon species, all on the Pacific Coast, are the Chinook (also called the king salmon), the sockeye, the silver, the humpback and the chum. The

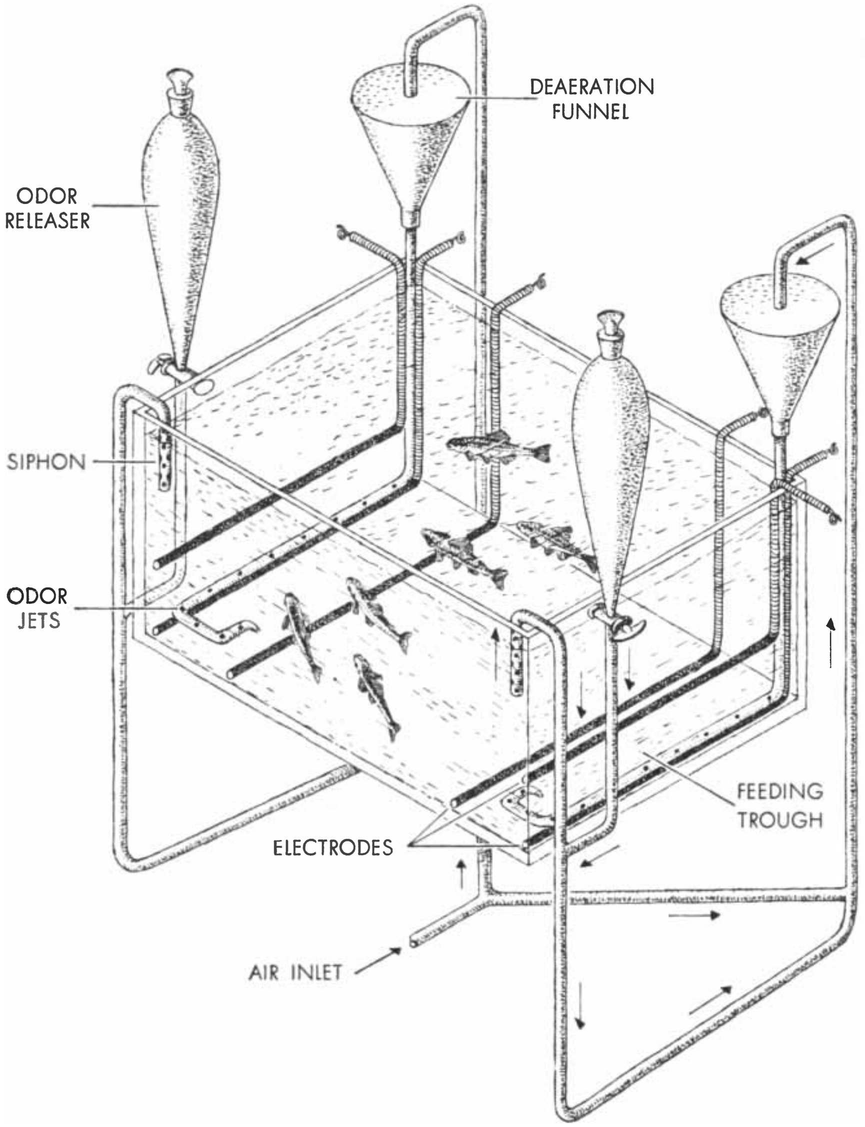


TWO COMMON SPECIES of salmon are (*top*) the Atlantic salmon (*Salmo salar*) and (*bottom*) the silver salmon (*Oncorhynchus kisutch*). The Atlantic salmon goes upstream to spawn year after year; the silver salmon, like other Pacific species, spawns only once.

Pacific salmon home only once: after spawning they die.

A young salmon first sees the light of day when it hatches and wriggles up through the pebbles of the stream where the egg was laid and fertilized. For a few weeks the fingerling feeds on insects and small aquatic animals. Then it answers its first migratory call and swims downstream to the sea. It must survive many hazards to mature: an estimated 15 per cent of the young salmon are lost at every large dam, such as Bonneville, on the downstream trip; others die in polluted streams; many are swallowed up by bigger fish in the ocean. When, after several years in the sea, the salmon is ready to spawn, it responds to the second great migratory call. It finds the mouth of the river by which it entered the ocean and then swims steadily upstream, unerringly choosing the correct turn at each tributary fork, until it arrives at the stream where it was hatched. Generation after generation, families of salmon return to the same rivulet so consistently that populations in streams not far apart follow distinctly separate lines of evolution.

The homing behavior of the salmon has been convincingly documented by many studies since the turn of the century. One of the most elaborate was made by Andrew L. Pritchard, Wilbert A. Clemens and Russell E. Foerster in Canada. They marked 469,326 young sockeye salmon born in a tributary of the Fraser River, and they recovered nearly 11,000 of these in the same parent stream after the fishes' migration to the ocean and back. What is more, not one of the marked fish was ever found to have strayed to another stream. This remarkable demonstration of the salmon's precision in homing has presented an exciting challenge to investigators.

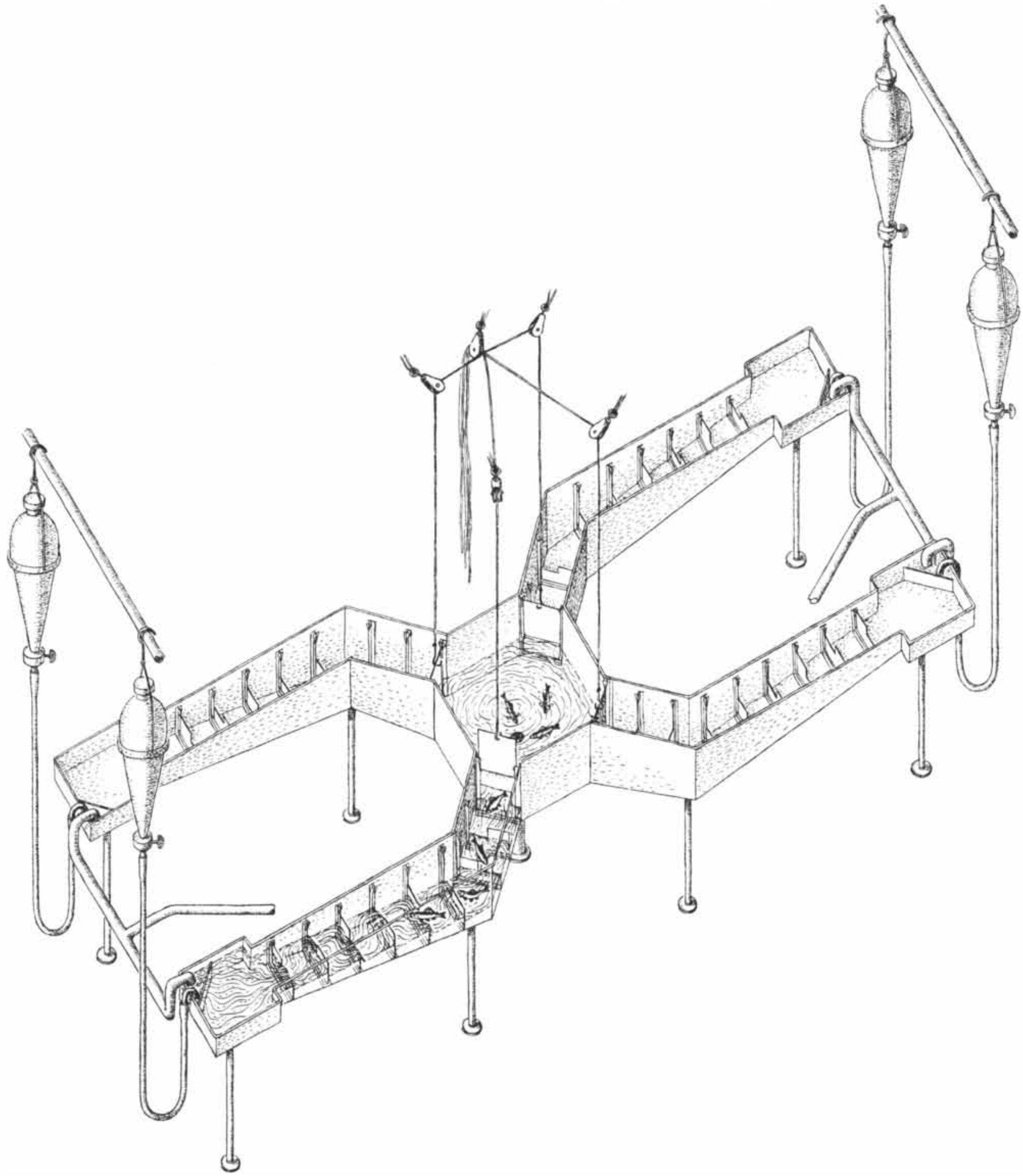


EXPERIMENTAL TANK was built in the Wisconsin Lake Laboratory to train fish to discriminate between two odors. In this isometric drawing the vessel at the left above the tank contains water of one odor. The vessel at the right contains water of another odor. When the valve below one of the vessels was opened, the water in it was mixed with water siphoned out of the tank. The mixed water was then pumped into the tank by air. When the fish (minnows or salmon) moved toward one of the odors, they were rewarded with food. When they moved toward the other odor, they were punished with a mild electric shock from the electrodes mounted inside the tank. Each of the fish was blinded to make sure that it would not associate reward and punishment with the movements of the experimenters.

At the Wisconsin Lake Laboratory during the past decade we have been studying the sense of smell in fish, beginning with minnows and going on to salmon. Our findings suggest that the salmon identifies the stream of its birth by odor and literally smells its way home from the sea.

Fish have an extremely sensitive sense of smell. This has often been observed by students of fish behavior. Karl von Frisch showed that odors from the injured skin of a fish produce a fright reaction among its schoolmates. He once noticed that when a bird dropped an injured fish in the water, the school of fish from which it had been seized quickly dispersed and later avoided the area. It is well known that sharks and tuna are drawn to a vessel by the odor of bait in the water. Indeed, the time-honored custom of spitting on bait may be founded on something more than superstition; laboratory studies have proved that human saliva is quite stimulating to the taste buds of a bullhead. The sense of taste of course is closely allied to the sense of smell. The bullhead has taste buds all over the surface of its body; they are especially numerous on its whiskers. It will quickly grab for a piece of meat that touches any part of its skin. But it becomes insensitive to taste and will not respond in this way if a nerve serving the skin buds is cut.

The smelling organs of fish have evolved in a great variety of forms. In the bony fishes the nose pits have two separate openings. The fish takes water into the front opening as it swims or breathes (sometimes assisting the intake with cilia), and then the water passes out through the second opening, which may be opened and closed rhythmically by the fish's breathing. Any odorous substances in the water stimulate the nasal receptors chemically, perhaps by an effect on enzyme reactions, and the re-



FOUR RUNWAYS are used to test the reaction of untrained salmon fingerlings to various odors. Water is introduced at the outer end of each runway and flows down a series of steps into a central compartment, where it drains. In the runway at the lower left the water cascades down to the central compartment in a series of miniature waterfalls; in the other runways the water is omitted to show the construction of the apparatus. Odors may be introduced into the apparatus from the vessels suspended above the runways. In an experiment salmon fingerlings are placed in the central compartment and an odor is introduced into one of the runways. When the four doors to the central compartment are opened, the fingerlings tend to enter the arms, proceeding upstream by jumping the waterfalls. Whether an odor attracts them, repels or has no effect is judged by the observed distribution of the fish in the runways.

sulting electrical impulses are relayed to the central nervous system by the olfactory nerve.

The human nose, and that of other land vertebrates, can smell a substance only if it is volatile and soluble in fat solvents. But in the final analysis smell is always aquatic, for a substance is not smelled until it passes into solution in the mucous film of the nasal passages. For fishes, of course, the odors are already in solution in their watery environment. Like any other animal, they can follow an odor to its source, as a hunting dog follows the scent of an animal. The quality or effect of a scent changes as the concentration changes; everyone knows that an odor may be pleasant at one concentration and unpleasant at another.

When we began our experiments, we first undertook to find out whether fish could distinguish the odors of different water plants. We used a specially developed aquarium with jets which could inject odors into the water. For responding to one odor (by moving toward the jet), the fish were rewarded with food; for responding to another odor, they were punished with a mild electric shock. After the fish were trained to make choices between odors, they were tested on dilute rinses from 14 different aquatic plants. They proved able to distinguish the odors of all these plants from one another.

Plants must play an important role in the life of many freshwater fish. Their odors may guide fish to feeding grounds when visibility is poor, as in muddy water or at night, and they may hold young fish from straying from protective cover. Odors may also warn fish away from poisons. In fact, we discovered that fish could be put to use to assay industrial pollutants: our trained minnows were able to detect phenol, a common pollutant, at concentrations far below those detectable by man.

All this suggested a clear-cut working hypothesis for investigating the mystery of the homing of salmon. We can suppose that every little stream has its own characteristic odor, which stays the same year after year; that young salmon become conditioned to this odor before they go to sea; that they remember the odor as they grow to maturity, and that they are able to find it and follow it to its source when they come back upstream to spawn.

Plainly there are quite a few ifs in this theory. The first one we tested was the question: Does each stream have its own odor? We took water from two creeks in Wisconsin and investigated whether fish could learn to discriminate between them. Our subjects, first minnows and then salmon, were indeed able to detect a difference. If, however, we destroyed a fish's nose tissue, it was no longer able to distinguish between the two water samples.

Chemical analysis indicated that the only major difference between the two waters lay in the organic material. By testing the fish with various fractions of the water separated by distillation, we confirmed that the identifying material was some volatile organic substance.

The idea that fish are guided by odors in their migrations was further supported by a field test. From each of two different branches of the Issaquah River in the State of Washington we took a number of sexually ripe silver salmon which had come home to spawn. We then plugged with cotton the noses of half the fish in each group and placed all the salmon in the river below the fork to make the upstream run again. Most of the fish with unplugged noses swam back to the stream they had selected the first time. But the "odor-blinded" fish migrated back in random fashion, picking the wrong stream as often as the right one.

In 1949 eggs from salmon of the Horsefly River in British Columbia were hatched and reared in a hatchery in a tributary called the Little Horsefly. Then they were flown a considerable distance and released in the main Horsefly River, from which they migrated to the sea. Three years later 13 of them had returned to their rearing place in the Little Horsefly, according to the report of the Canadian experimenters.

In our own laboratory experiments we tested the memory of fish for odors and found that they retained the ability to differentiate between odors for a long period after their training. Young fish remembered odors better than the old. That animals "remember" conditioning to which they have been exposed in their youth, and act accordingly, has been demonstrated in other fields. For instance, there is a fly which normally lays its eggs on the larvae of the flour moth, where the fly larvae then hatch and develop. But if larvae of this fly are raised on another host, the beeswax moth, when the flies mature they will seek out beeswax moth larvae on which to lay their eggs, in preference to the traditional host.

With respect to the homing of salmon we have shown, then, that different streams have different odors, that salmon respond to these odors and that they remember odors to which they have been conditioned. The next question is: Is a salmon's homeward migration guided solely by its sense of smell? If we could decoy homing salmon to a stream other than their birthplace, by means of an odor to which they were conditioned artificially, we might have not only a solution to the riddle that has puzzled scientists but also a practical means of saving the salmon—guiding them to breeding streams not obstructed by dams.

We set out to find a suitable substance to which salmon could be conditioned. A student, W. J. Wisby, and I [Arthur Hasler] designed an apparatus to test the reactions of salmon to various organic odors. It consists of a compartment from which radiate four runways, each with several steps which the fish must jump to climb the runway. Water cascades down each of the arms. An odorous substance is introduced into one of the arms, and its effect on the fish is judged by whether the odor appears to attract fish into that arm, to repel them or to be indifferent to them.

We needed a substance which initially would not be either attractive or repellent to salmon but to which they could be conditioned so that it would attract them. After testing several score organic odors, we found that dilute solutions of morpholine neither attracted nor repelled salmon but were detectable by them in extremely low concentrations—as low as one part per million. It appears that morpholine fits the requirements for the substance needed: it is soluble in water; it is detectable in extremely low concentrations; it is chemically stable under stream conditions. It is neither an attractant nor a repellent to unconditioned salmon, and would have meaning only to those conditioned to it.

Federal collaborators of ours are now conducting field tests on the Pacific Coast to learn whether salmon fry and fingerlings which have been conditioned to morpholine can be decoyed to a stream other than that of their birth when they return from the sea to spawn. Unfortunately this type of experiment may not be decisive. If the salmon are not decoyed to the new stream, it may simply mean that they cannot be drawn by a single substance but will react only to a combination of subtle odors in their parent stream. Perhaps adding morpholine to the water is like adding the whistle of a freight train to the quiet strains of a violin, cello and flute. The salmon may still seek out the subtle harmonies of an odor combination to which they have been reacting by instinct for centuries. But there is still hope that they may respond to the call of the whistle.

46 Major Projects at Lockheed

Advance Careers of Engineers

Lockheed projects cover virtually the entire spectrum of aeronautical engineering endeavor, including turbo-prop, turbo-compound and jet transports; jet fighters, trainers and bombers; vertical rising aircraft; nuclear applications to aircraft and many other significant classified activities.

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A report on "High Heat Treat Steel" taken from one of Lockheed's monthly engineering and manufacturing forums is available to interested engineers. Address requests to the forum chairman, E. H. Spaulding.

Engineers interested in Lockheed's expanding development and production program are invited to write to E. W. Des Lauriers, Dept. MP-12-8.

Below: Lockheed engineers at work on various projects

Operations Research study on overseas transport routes

Aerodynamic meeting on high-speed fighter

Fatigue test on Super Constellation skin

Antenna pattern study on radar search plane

Design study on hydraulic requirements of new transport

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The Changing American Language

In spite of education and communication our speech continues to evolve with such phenomena as palatalization, epenthesis, aphaeresis, anaptyxis, apocope, syncope, and recessive accent

by Jotham Johnson

If Shakespeare suddenly turned up and tried to talk to us, we would have difficulty understanding him. If Chaucer did, we wouldn't be able to understand him at all. The English language has changed tremendously in the last few hundred years; for illustration, we can amuse ourselves by comparing these few Old English words with their modern equivalents: cyning (king), hlaefdige (lady), macode (made).

Is the language still changing? Many people suppose that mass education and mass communications are stabilizing it, and that from now on speech changes will be negligible. But your own ears tell you that this is not so. The varieties of pronunciation that betray a language in flux can be heard from region to region in the nation—indeed, from borough to borough in New York City. New variants in speech, spreading over the nation and becoming dominant, are continually changing the language. Let me show you, with a few examples, why I think so.

Take the sound of *oo* in ooze. There is a class of words in which we always put a *y* sound in front of the *oo* sound; sometimes we write the *y* (as in yew, you, youth, Yule) and sometimes we do not, though we pronounce it (as in cube, eureka, Hugh, union, volume). Spelling is no good guide; it is our ears that tell us to pronounce *yoo* in abuse, beauty, cue, ewe, few, fuel, music, queue, view. Then there is another class of words in which *oo* is never preceded by a *y* sound: boo, fool, goose, lose, soup, who and so on. But now there is also a third class of words which are pronounced sometimes with a *y* sound and sometimes without: *e.g.*, due, endure, lure, new, suit, produce. No two persons are likely to agree on which of these words should have a *y* before the *oo*. Do you say lyoorid or loorid? Here is a change in speech that we can observe in transition. Probably in the future one or the other form will be adopted as correct usage and we shall have doo or dyoo, nooz or nyooz, but not the alternative as at present.

When the *y* sound before *oo* is preceded by *t*, the combination tends to become *ch*: century, contemptuous, future, picture, naturally (natch!). This is true even when the sequence is in separate words: I bet you (betchoo), I hate you (haychoo), eat your cereal (eatchoor cereal). Comic strips and some other contemporary literature (literachoor) recognize the prevalence of these forms in speech by spelling them that way: aintcha, arentcha, betcha, *etc.*

Suppose you are in the fix, described earlier, where you are in doubt whether to put a *y* before the *oo* and now find it preceded by a *t*. What do you do? If you say Toosday, the *t* is safe from attack, but if you try to say Tyoosday, you are almost certain to end up with Choosday. There are many words wandering uncertainly in this phonetic no-man's land: attitude (attitood or attichood?), stupid (stoopid or schewpid?), tune (toon or choon?). A prize specimen is nuptial, usually nupshul but occasionally pronounced nupchooal, as if it were spelled nuptual. This pronunciation may derive by inattentive analogy from certain

Could we understand the speech of Shakespeare (left)? *Of Chaucer* (right)?

words ending in tual (*e.g.*, punctual, ritual, spiritual).

What happens to *d*, the near relative of *t*, when it is followed by *y*? *Dy* tends to become *j:* gradual, schedule, did you (didja), could you (cooja), did you eat yet? (jeetchet?). The college columnist who rhymed "asked yet" with gas jet was not indulging his fancy; he was recording, with merciless precision, a pronunciation he had clearly heard.

Here, too, what happens to *d* depends on whether or not the individual (indivijual) speaker elects to put a *y* after it. Deuce may be dooce or dyooce, but any effort to say dyooce is likely to end up jooce. The chancellor of a Canadian university invited me to enjoy myself "juring" my stay in his city.

A word like idiot offers no problem as long as all three syllables are pronounced (id-ee-ut). But there is a tendency in British and American speech to shorten such words by changing the *ee* to *y* (*cf.* devious—deevyus). Thus idiot becomes idyut and then ijut. In the comics and TV programs that cater to juveniles, Injun has just about driven Indian out of circulation. In the same class are fastidious and immediately, and I am quite sure I have heard rayjo for radio and rayjent for radiant.

Under the influence of analogy with words such as devious, other words ending in *ous* may acquire *i* as an extra syllable: a particularly flagrant example is "mischievious." Such an insertion of *i* must account for the development of tremendous into tremenjus.

The introduction of a *y* sound before a vowel is called palatalization, because in pronouncing *y* the tongue is humped up toward the palate. Palatalization has influenced many sound changes in English besides those already mentioned. For instance, *s* followed by *y* has become *sh*; that explains the pronunciation of sugar, sumac, sure, sensual, sexual and so on. It also explains the pronunciation of words such as nation, where the *t* long ago came to be pronounced *s*, and spacious, where the *c* likewise took the sound *s*. The change of *sy* to *sh* also operates between words: I'll miss you (mis-shoo), can't place you (play-shoo).

Similarly the sound of *z* followed by the sound of *y* becomes the sound *zh*, as in leisure, measure, usual, azure, confusion, Parisian, raise your hands (rayzhoor hands).

We should not overlook the reverse phenomenon of depalatalization: the dropping of *y* before vowels in words where it used to be generally pronounced. Examples include costume (costoom), figure (figger), ridiculous (ridickalus). The spelling "vittles" suggests how long this sort of thing has been going on.

Many Americans pronounce the word nuptial as though it were spelled nuptual

Besides palatalization there are a dozen other types of change which I suspect threaten the integrity of the speech of our time, but I cannot take them up in great detail. Let me instead list in very brief form a selection of such changes, with a few examples of each. Most of them have affected a number of languages and were encountered in classical Greek and Latin, which accounts for the Greek names some of them bear.

Sometimes you hear a consonant inserted where the spelling of the word suggests no such sound: fambly for family, chimbley for chimney. The name of this phenomenon, from the Greek, is "epenthesis." Our best families look upon epenthesis as characteristic of the speech of the underprivileged classes, but there are scores of such usages on which the passage of time and the dictionary have bestowed dignity and honor: humble for the original humil, nimble for nimel, number from the Latin numerus. From the lips of our most careful speakers you will hear empty (originally emti), Simpson (Simon's son), gender (genre), seamstress (sempstress).

Goomby for goodby is a special case which derives from modern Greek. In modern Greek the sound of *b* is expressed not by the letter *beta* (which has the sound of *v*) but by the combination *mu pi* (*mp*), because *pi* after *mu* or *nu* has come to be sounded as *b*. As a consequence it is hard for a Greek without special training to say goodby or goo'by; it is natural for him to say goomby. This Grecism has also had its effect on the names of certain foods served in restaurants: bloomberry pie, stromberry pie.

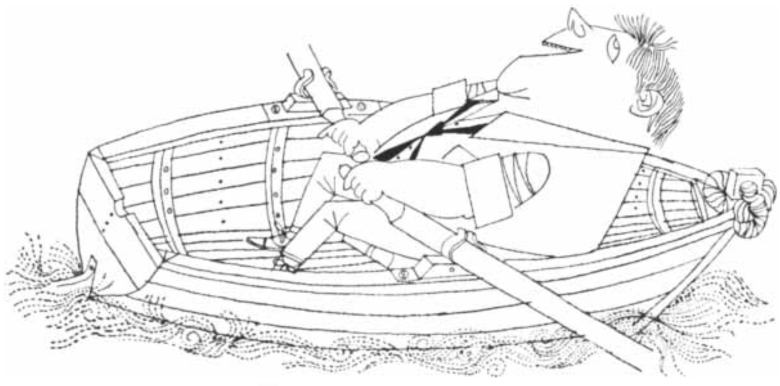
The insertion of an extra vowel in the body of a word, giving rise to an additional syllable, is called "anaptyxis." Note athaletic, ellum, fillum, siggunel, mischievious, momentuous and "he ran thataway." The Detroit suburb spelled Hamtramck is usually pronounced Hamtrammick.

The omission of sounds or syllables from a word is regarded as a particular characteristic of American speech, but the English have tried manfully to do

A Brooklynite might well say: "Things are in a toimerl"

their share. It has been going on for centuries. Thus we have bus (omnibus), coon (raccoon), cute (acute), fence (defence), phone (telephone), possum (opossum), sample (example), Sandra (Alexandra), spend (expend), sport (disport), tawdry (Saint Audrey), van (caravan) and innumerable others. The name for this sort of thing is "aphaeresis," and it is safe to predict that aphaeresis will continue to contribute new forms to American and English speech. Forms not yet admitted to the dictionaries are to be heard on every corner: for example, lectric (electric), pologize (apologize).

Omissions at the end of the word, called "apocope," include: ad (advertisement), bunk (buncombe), champ (champion), doc (doctor), dorm (dormitory), mike (microphone), scram (scramble), vamp (vampire) and others considered as only slightly more acceptable: auto, coed, exam, gym, lab. Americans who regard such vulgarisms with dismay do not hesitate to employ cab (cabriolet), cable (cablegram), can (canister), cinema (cinematograph), gin (Geneva), miss (mistress) and other



Between Oswego and Rochester people say "a roll in the bolt" for "a row in the boat" examples of apocope whose social standing has been endorsed by Webster.

Flu (influenza) and gyp (Egyptian) illustrate both aphaeresis and apocope. Darn, a pallid pinch hitter for damn, has been explained as the middle syllable of eternal (tarnal damnation).

As for elisions in the middle of a word, called syncope, even purists do not hesitate to say bedlam (Bethlehem), bizness (business), can't, don't, I'll, isn't, foksil (forecastle), leppard (leopard), maudlin (Magdalen), mineralogy (mineralology), pacifist (pacificist), Wenzday (Wednesday). The syncopation of words ending in *ary* and *ory* (litry for literary, militry for military, labratry for laboratory) is an Anglicism which never fails to delight the American ear. Syncope is common in proper names: Bennett (Benedict), Dennis (Dionysius), Jerome (Hieronymus). Syncope between words is illustrated by don't wantny (don't want any). Pram (perambulator) illustrates both syncope and apocope. The finest specimen in any word-hunter's bag is alms, telescoped from six syllables (eleëmosyne) to one. Of the same order is goodby (God be with ye).

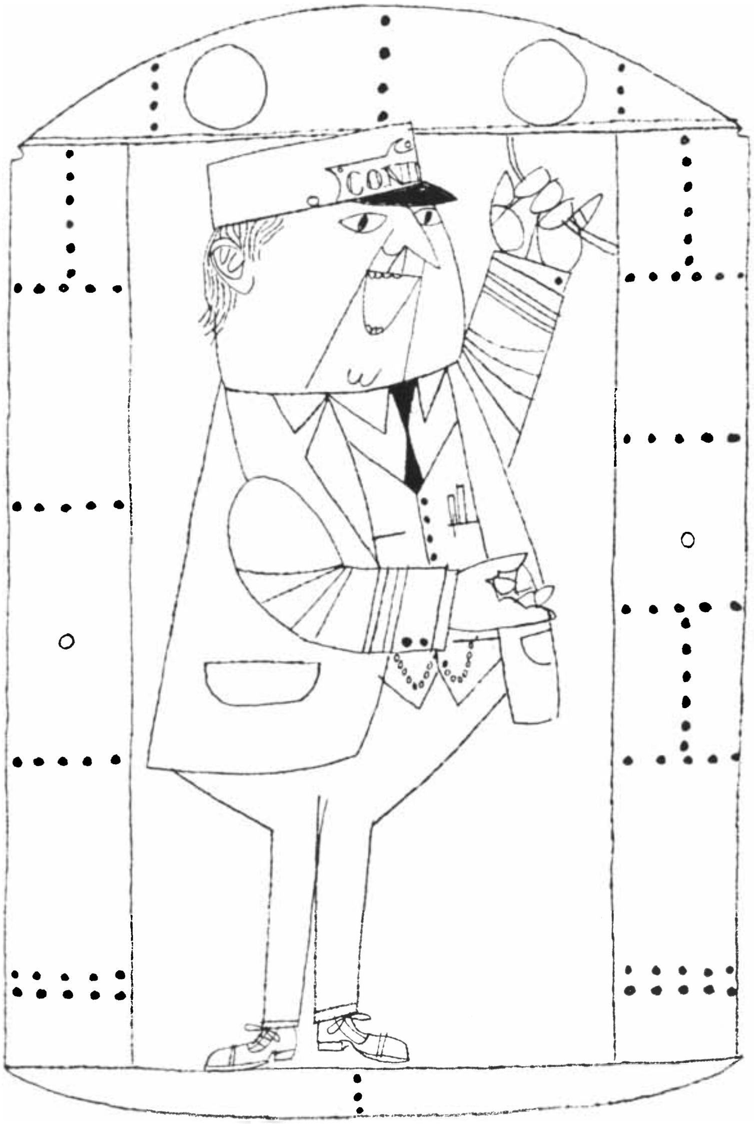
Because a final *s* or *z* sound is the ordinary sign of the plural in English, any singular ending in *s* or *z* is in danger of losing it, yielding a new singular form. Cherry, pea and shay came into the language from cerise, pease and chaise. The nursery rhyme "Pease porridge hot, pease porridge cold" preserves the old singular. Eaves, another singular, is beginning to appear as eave; I have a clipping which speaks of a man shooting a squirrel on the "eave" of his house, and an archaeological pamphlet speaks of an "eave-trough." This explains, too, the forms Chinee and Portugee. At least one word, however, has changed in the opposite direction: shamble has acquired a plural ending, shambles, though it is still regarded as singular (this place is a shambles).

By inversion of sounds, called "metathesis," many speakers change apron to apern, ask to ax, cavalry to calvary, children to childern, hundred to hunderd, modern to modren, perhaps to prehaps, perspiration to prespiration and saliva to salvia (the sage plant). Metathesis is regarded as a mark of substandard speech by the same people who do not hesitate to say custard (originally crusted), daffodil (asphodel), iern (iron), task (tax), third (thridde). In a class by itself is excape, with a metathetic *k* before the *s* and another *k* after it.

Then there is "assimilation"—the phenomenon seen in gimme, lemme, twenny, sujjest (sug-gest), wanna, gonna. These are considered examples of slovenly speech, but other assimilations are perfectly proper: attitude (aptitude), gossip (godsibb), kloz (clothes), lissen (listen), offen (often), pennant (pendant). Assimilation does not seem to be a powerful force in contemporary sound changes, but it may operate on the heels of other changes. The fate of the *v* before *m* in gimme suggests what may happen to "guv'ment." Has Sat'day already become Sadday? I occasionally see it so written.

The opposite of assimilation, "dissimilation," accounts for the *r* which we pronounce but do not write in colonel, and the *l* in mulberry, originally murberry. We irregularly and inconsistently avoid repeating the same consonant in neighboring syllables. Paper, through dissimilation, became taper; both survived, and we have paper and taper side by side. Chimley (whence chimbley) is apparently a dissimilated form of chimney. Febuary (February) is another example; the first *r* has been dissimilated to *y*. Seckatery (secretary) results from the effort to avoid two *r*'s in the word. Pronounce negotiation and listen carefully: Do you say "negosheeayshun" or "negoseeayshun?"

Add to these specimens the "recessive accent"—stressing of the first syllable of a word which has previously been accented on the second or third syllable. The following illustrations only skim the cream: ápplicable (formerly applícable), cígarette (cigarétte), cóntemplate (contémplate), cóntrary (contráry—the nursery rhyme is holding things up here), córollary (coróllary), décadent (decádent), démonstrate (demónstrate),

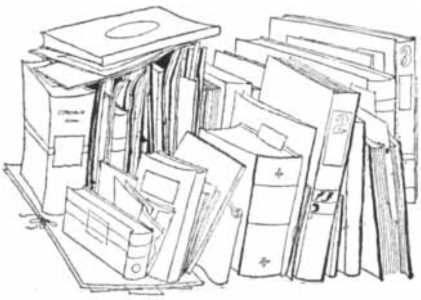


The conductor of a Boston streetcar said: "This ca goes as fa as Pak Street" déspicable (despícable), éxquisite (exquísite), ménu (menú), mústache (mustáche), quándary (quandáry), ródeo (rodéo), víolin (violín). In most of these cases the accent on the first syllable has become standard in American. Something should be done to stop people from saying theáter, but it is not safe to tell them always to put the accent on the first syllable in a three-syllable word, because then you will hear cónsumer, ínclement and óbjector. While almost everyone says piáno, this agreement does not apply when it comes to piánist versus píanist; both are in vogue and the uncertainty causes large areas of the population to avoid them both, seeking refuge in piáno player.

I have no more than rippled the surface of this scientific backwater; this article does not pretend to cover all the categories of change in the contemporary speech of America. Whenever we hear different pronunciations of the same word, or pronunciations incompatible with the spelling, we must realize that some change has occurred or is trying to occur in the language. To be sure, some of the varieties of speech are mere localisms. One is the famous New York inversion of *oi* and *er*—boid for bird, terlet for toilet. Some of my friends insist they have actually encountered toimerl for turmoil, but to my disappointment I have never heard this classic. In Boston I heard a subway conductor announce, giving *a* the sound it has in ask: "This ca only goes as fa as Pak Street." In northern New York, along the south shore of Lake Ontario, the local speciality is an *o* so long that it seems to carry an *l* with it. I have heard: "Put on your colt and we'll go for a roll in the bolt" (put on your coat and we'll go for a row in the boat).

The moral is that changes in pronunciation and eventually in the word itself are normal phenomena of speech. They have been going on since speech was invented, and the efforts of purists to halt such changes have generally been in vain; indeed, many have slipped by without protest. There is no reason to believe that the factors which produce these changes, whatever they are, have lost their potency in the U. S. today.

I regard myself as on the side of the angels: I deal instantly and harshly with any student who says fambly, Febuary, fillum, modren, pome, Sadday or "different than." But purists in general are whistling in a cyclone. You may think it is funny to say "veddy, veddy Briddish." But are you sure you don't say: "What's the madder?"



BOOKS

A new life of the remarkably modern 18th-century philosopher David Hume

by Stuart Hampshire

THE LIFE OF DAVID HUME, by Ernest Campbell Mossner. University of Texas Press ($7.50).

Adam Smith said of Hume: "Upon the whole, I have always considered him, both in his lifetime and since his death, as approaching as nearly to the idea of a perfectly wise and virtuous man as perhaps the nature of human frailty will admit." After nearly two centuries there still seems no ground for disagreement with his verdict. In Professor Mossner's life of Hume we have all the facts before us more fully than ever before. It is now possible to catch the exact tone of voice, and to understand the temperament, which formed Hume's style and thought. He still appears as the most philosophical of all modern philosophers—unalterably sane, detached, critical, gay and undeceived, at once profound and clear.

Hume saw almost every theoretical issue from a superior vantage point, with a landscape of alternative ways of approach lying on either side of the question. He never took a side in morality, politics or history without suggesting the possibility of doubt and the uncertainty of his opinion. His philosophy developed from a single and unchanging insight: that none of man's beliefs in any domain (outside the formal deductions of mathematics) can be given the stamp of certainty by any final, deductive proof. But he saw two sides even to this skeptical assertion. One must not infer from it that the ordinary beliefs of the ordinary man are unacceptable and must be rejected by a philosopher. On the contrary, the true inference is that philosophical criticism of ordinary beliefs can rest on no foundation in reason. Nature has implanted in us the tendency to form certain beliefs in accordance with certain psychological habits which are fixed and constant in all men. It is the proper work of the philosopher to state what these habits are and to show that, in the last analysis, they are no more than inborn habits. But if a philosopher cannot justify our habits of inference, he equally cannot replace them by anything more rationally satisfying, for there is not, and could not be, any self-evident truth, or demonstrable proposition, which would serve as a rule of inference from one matter of fact to another. The philosopher can only show the hopelessness of looking for any such ultimate justification of his customary beliefs. And he will then return to these beliefs, having understood that reason by itself is powerless to settle any matter of fact, and that he cannot in any case prevent himself from following those habits of belief and feeling which nature has implanted in him.

Hume thought that he had finally destroyed the old philosophical program of finding some external criterion of rationality by which to assess our ordinary claims to knowledge. He believed that he had shown that the distinction between rational and irrational beliefs is the same as the distinction between beliefs founded on regularities in our experience and beliefs founded not on regularities but on a disordered imagination. We cannot meaningfully look for any further sense of "rational." As philosophers, we must in the end return to the common sense from which our speculative quest began. In the course of the inquiry we have learned to recognize the limits of human reason and therefore to see that philosophical speculation must be empty whenever it tries to go beyond the narrow limits of experience. We would do well to burn all the traditional works of metaphysics, unless they contain observations on matters of fact which might be tested in experience. If they do contain philosophical observations on matters of fact, they will belong to the moral sciences which systematically study the workings of the human mind. Hume thought of his own philosophy as moral science: he was generalizing about the workings of the imagination and sentiments and passions on which all our beliefs and actions depend. Philosophy, as moral science, was still the first and most profound of the sciences, for it traced those general habits of inference which were essential to every other inquiry.

Hume's philosophy presented itself to him as an inspiration in the spring of 1729, when he was only 18. The outline of the new "science of man," depending on an understanding of the nature of causal inference, was suddenly fixed in his mind forever. "There is no question of importance whose decision is not comprised in the science of man; and there is none which can be decided with any certainty before we become acquainted with that science. In pretending, therefore, to explain the principles of human nature, we in effect propose a complete system of the sciences, built on a foundation almost entirely new, and the only one upon which they can stand with any security." The pattern of his life, as Professor Mossner shows, was set by this early vision, which he expressed in terms so startingly like Descartes's earlier vision of the new foundations of science. Hume henceforth knew what he had to do, and his life's work was a methodical exploration of this single insight.

There were only two serious interruptions of his work. The first was an emotional crisis which came immediately after his discovery of the new philosophy in 1729. It was a familiar form of extreme depression. Hume, with that Scottish good sense which was so characteristic of him, attributed his collapse to physical causes and decided that he must be more moderate and less enthusiastic in his studies. Professor Mossner quotes the magnificently intelligent letter to an unknown doctor in which Hume analyzed his own symptoms. No one who has read it can any longer think of Hume merely as "le bon David"—a superficial, easy, comfortable person who simply formed his philosophy in his own image. Professor Mossner remarks that his impulses and true nature did not lie on the surface and that, in spite of his autobiography, he was a reticent and concealing man. Hume seems to have undergone a kind of conversion in 1729, a turning away from enthusiasm toward the detached, and even ironical, attitude to experience which he maintained to the last, and which fascinated Boswell when he visited him on his deathbed. "Enthusiasm" became to Hume a word of abuse, and he was never again to be deeply committed to any cause or any person.

The second interruption was occasioned by the total and unexpected failure of his *Treatise of Human Nature*, which dropped "dead-born" from the press in 1738 and aroused absolutely no interest in the learned world. The failure of the *Treatise* amazed Hume. He knew that it was one of the great achievements of human thought, which should open a new phase in philosophy. His contemporaries did not understand his design and missed the real point of his argument. The time was too early. Kant, at the turn of the 19th century, was the first to see that Hume had made it necessary for philosophy to make a fresh start if its claims as a contribution to knowledge were any longer to be taken seriously.

After a moment of despair over the dismissal of the *Treatise*, Hume started again, using the weapons of "patience, exile and cunning" to achieve literary fame by more indirect means. He wrote a short abstract of the treatise, simplifying and popularizing his doctrine. This also was unsuccessful. But his *Essays, Moral & Political*, which appeared in 1741, caught on, and the second volume of the *Essays* in the following year established Hume as a writer. In the *Essays* he slipped in his revolutionary doctrine under the disguise of belles-lettres. The 18th-century reading public was as complacent and easygoing as the circulating-library public of a later age; it was accustomed to the Addisonian essay as a later public was accustomed to the three-decker novel. Hume accepted the convention and slyly and successfully worked within its limits. It is typical of his temperament and philosophy that he should in this way have abandoned the ideal and accepted the possible.

It was in the natural order of Hume's thought to put metaphysics behind him, once he had finally settled its limits. He turned to the study of history, the proper study of man, which alone could show the actual influence of the various passions and sentiments and, above all, the influence of custom. Hume's great *History of England*, so much admired in his own time, may seem to a modern reader unlike what history should be. There is little sifting of evidence or return to original sources, and there is no very detailed narrative. He was chiefly interested in the broad generalities of human behavior and in drawing a moral from them. But, together with Voltaire, he was the precursor of the age of historical thinking. Hume made history popular, and no other historian until Macaulay was to make so profound an impression.

Hume thought of human nature as governed by laws analogous to Newton's laws of motion. The law of the association of ideas, analogous to the law of gravitation, would explain the various operations of the mind. The psychological laws must be no less universal than their physical counterparts. Like later fellow philosophers in France, Hume conceived human nature as essentially unchanging, not evolving gradually. But, unlike the Encyclopedists, he deduced human nature not only from *a priori* principles but also from a search of the facts of history for the psychological roots of fanaticism and superstition. Of the two leading slogans of the 18th-century enlightenment, Reason and Nature, he took only the second seriously. In politics, as in any matter of belief or attitude, reason must be the slave of the passions; that is, it is both psychologically impossible and logically indefensible to base decisions of policy on purely theoretical, rational principles. Hume distinguished between "political Whigs" and "religious Whigs," "political Tories" and "religious Tories." The political partisans were those who based their attitudes on expediency; the religious ones made their attitudes a matter of principle. Hume believed the latter were bad because fanatical; he was himself a po-

This engraving of Hume was based on a portrait painted by Allan Ramsay litical Tory. In writing of the Ideal Commonwealth, and elsewhere, he subtly and quietly stated the case for gradual change which Burke and Bagehot were to overelaborate later. Man has a natural propensity to be guided by habit and custom. But it is also a fact of human nature that men look for improvement and are emotionally interested in human welfare; they sympathize imaginatively with the misfortunes of others, particularly those near to them. The wise or philosophical man will therefore look in politics for a natural balance between these two tendencies of human nature—the inertia of custom and the desire for improvement. Both of these tendencies are animated by feelings, not by logic.

In the last analysis Hume's true greatness lies in the original philosophical insight which he first stated in the *Treatise* and later developed and applied in his *Dialogues on Natural Religion*. This insight may be summed up in the word empiricism. The range of his discovery was not fully understood until this century. Now, through Bertrand Russell, almost all British and American empiricists are to some degree disciples of Hume. Within the last 20 years he has come to be accepted as probably the greatest of all philosophers who have written in English.

Hume stated his argument in psychological terms, starting from a metaphysical premise: "All the perceptions of the human mind resolve themselves into two distinct kinds which I shall call impressions and ideas." He then asserted that all distinct perceptions must be distinct existences, and that any connections which the mind finds between them must be imposed by the mind itself, following the psychological law of the association of ideas. We have no conceivable ground on which to make a philosophical distinction between the objective nature of reality and the order of our perceptions. All inferences which lead to conclusions beyond our particular perceptions must be founded on the relation of cause and effect, and this relation itself, when analyzed, turns out to be a consequence of the association of ideas. We can find no ground external to our experience from which we can either criticize or justify any of our common-sense beliefs about the external world.

Almost none of Hume's followers today would accept the terms in which he stated the argument. It is now stated not in psychological terms but rather in linguistic or logical terms. This is certainly a very great gain in clarity, since it shows that philosophy is not an empirical inquiry or a branch of science in any ordinary sense. It becomes easier to see that, in analyzing the assertions of science or other statements, philosophers are looking for the most general rules governing thought and language, not merely collecting actual habits of speech or thought. This notion of the fundamental rules, rather than the fundamental habits, of thought was Kant's addition to Hume. While Kant still wrote of the inescapable categories of thought in quasi-psychological terms, as though they were compulsions which the mind somehow imposes upon itself, he also distinguished the ultimate forms and rules of thought from mere psychological generalizations. And he deduced his list of rules that govern all our thought and experience from the logical forms of our statements. Kant's Critical Philosophy may be said to be a development of Hume's criticism of metaphysics, with the role of critical philosophy carefully distinguished from that of science, and with the limitations of reason shown to rest in the very nature of thought and judgment, which cannot go beyond the limits of experience.

Hume's argument can easily be refuted as argument, and has often been refuted by much lesser philosophers, for example, by his 19th-century critic T. H. Green. Its weakness is that the argument throughout presupposes, or merely asserts, what it purports to prove: *e.g.*, the assertion that all distinct ideas are distinct existences. Yet history shows that the strength of the great philosophical ideas has not generally rested on the strength of the arguments used to support them. In the long run the power of a philosophical discovery resides in the central insight—the appreciation of a truism previously overlooked. Hume's truisms were, first, that we can discover causes and effects only by observation and experiment, not by *a priori* reasoning, and secondly, that from no set of statements of what actually exists can we validly deduce any proposition about what ought to be done or what ought to exist. Modern philosophy began with the recognition of these two truths.

Professor Mossner's book is not intended to include serious exposition of Hume's thought, but he has written a masterly biography of the man. His research has enabled him to recreate the life of Edinburgh, which was Hume's background, much more fully than it has ever been done before. He carefully traces and interprets Hume's famous quarrel with Rousseau. My own guess—and it is no more than a guess—is that Rousseau found in Horace Walpole's England the type of society which he most detested: he was both shocked and humiliated by its aristocratic toughness and its dry, cackling mockery of everything soft or weak. Hume, for his part, did not even begin to understand the absolute and unconditional devotion that his friend demanded of him. Professor Mossner shows Hume, in all his relations with people, fencing for independence, always withdrawing, always uncommitted. He passed in and out of the literary and social life of London, obstinately returning from this foreign capital to his provincial independence. Perhaps Rousseau at the very beginning foresaw, with morbid acuity, the potential curve of his relations with Hume and the inevitability of Hume's ultimate withdrawal, and therefore invented charges which were a dramatization of the future betrayal. In temperament Hume and Rousseau were the antitheses of each other, but intellectually they had a point of contact which separated both of them from the Encyclopedists. Neither believed that social and political problems could be solved by rational analysis and scientific method, or that men could be guided by rational calculation. Hume not only did not share the Encyclopedists' simple faith in reason and science but was repelled by their enthusiasm, for enthusiasm, either of belief or nonbelief, seemed to him the prime intellectual error. Professor Mossner describes the amusement of Hume's French friends when he refused to embrace their atheism. They could not understand why he should think any downright assertion in this domain merely absurd. The depth of his skepticism could not be understood; he had jumped ahead, while French thought was still assimilating Locke and discarding Descartes.

Professor Mossner sometimes writes inelegantly, and a reader may lose his direction in the accumulations of detail, not always strictly relevant; there is little form or design in this book. But there is a generosity which makes one forget the formlessness. All the great scenes of Hume's life are described and documented, and Mossner's admiration and devotion are communicated to the reader: Hume as the man of affairs in the Embassy at Paris; Hume as the literary and social hero of Paris salons, lapped in feminine flattery, speaking comical French with a Scottish accent; Hume carefully eliminating Scotticisms from the writings of his friends; Hume competing for professorships in Edinburgh and being defeated by the bigots; Hume cultivating idleness and calmly making arrangements in anticipation of his death. There is an unforgettable picture

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of Boswell, wild and staring, at the funeral of the great infidel, who had not repented even at the end. This is a splendidly successful book which will be indispensable both to students of Hume and to students of the 18th century.

Short Reviews

VARIATIONAL PRINCIPLES IN DYNAMICS AND QUANTUM THEORY, by Wolfgang Yourgau and Stanley Mandelstam. Pitman Publishing Corporation ($5.50). From the earliest times philosophers and scientists have sought to express the bewilderingly complex phenomena of nature in certain grand but simple principles. A single building block, the atom; a single governing entity for the universe, number; a single rule of scientific explanation, Occam's razor; a ruling principle of physical action, economy—these are examples of answers to the age-old quest. The authors of this monograph trace the development of the minimal principle of physics through its major stages. They discuss the rule of Hero of Alexandria that a ray of reflected light takes the shortest path from object to mirror to observer's eye; Fermat's principle of least time, an extension of Hero's law to refracted rays; Maupertuis's principle of least action; the magnificent translation of this principle by Euler, Lagrange, Hamilton and Jacobi into an exact analytical instrument; the further extension of the methods so derived to quantum theory, quantum mechanics and relativity. David Hilbert, the noted German mathematician, found a function, later identified with the "curvature" of the universe, which led Sir Edmund Whittaker to say of Hilbert's principle that "gravitation simply represents a continual effort of the universe to straighten itself out." The authors in their concluding chapter consider the metaphysical debate on the issue whether it is possible for man to know the real world. This is an unusually interesting, provocative book, clearly written. It will appeal to advanced students of mathematics and physics.

DILEMMAS, by Gilbert Ryle. Cambridge University Press ($2.00). "Dilemma," says a 16th-century treatise of logic, "otherwise . . . called a horned argument, is when the reason consisteth of repugnant members, so that what so ever you graunt, you fall into the snare." In this volume of Tarner Lectures, Professor Ryle, known for his excellent book *The Concept of Mind*, examines a number of philosophical snares which delight and trip up plain men as well as philosophers. Among the older and more famous riddles are those concerned with fatalism and Achilles' strenuous efforts to overtake the tortoise at the second milestone (he does, says Ryle). Ryle also discusses the nature of pleasure (is it properly conceived as the opposite of pain?), the relations between the world of science and the world of common sense, the relation between technical and nontechnical concepts, the problem of perception, the issue between formal and informal logic. Ryle is a clear, incisive thinker, skillful in breaking down elusive problems, in extracting the kernel and in showing how much of substance is enclosed by the hull of words. For example, he makes perfectly plain by a parable the source of the worry many of us have felt about the apparent conflict between the picture of the world we form from daily experience—the hard, smooth desk we write on—and the picture drawn by scientists—the quivering, discontinuous, wave-particle desk of physics. The pictures, as he shows, are entirely separate; they do not really contradict each other since they are not in competition. In fact it is the very misuse of the word "picture" that generates the confusion: the plain man and the physicist are engaged in different businesses and there is no point in politely pretending that they are engaged in "some joint but unobvious missionary enterprise" of providing complementary views of the world.

MAN MEETS DOG, by Konrad Z. Lorenz. Houghton Mifflin Company ($3.00). The many admirers of Konrad Lorenz will enjoy this affectionate study of the "canine personality" even though the book is not quite up to *King Solomon's Ring*. The master offers his now familiar and thoroughly palatable mixture of theories (some a little far-fetched), scientific observations (uncannily sharp), anecdotes (many quite touching) and astonishing personal experiences. Animals and Lorenz seem to get together on a higher plane of mutual understanding than has ever before been achieved. Lorenz gives counsel on the strain to choose if you want a fiercely faithful dog or an all-round amiable fellow, a jealous overseer of your children or a neighborhood Peter Pan. He interprets dog language and expressions and advises on what a dog can be taught and what can be expected of him. Animals of different species, says Lorenz, rarely become friends, but they can and often do find a *modus vivendi*. One of the best things to be gained from this book is a set of sensible, unsentimental rules which will permit you to lead your life, and your dog his, while preserving the dignity of both. The illustrations in the book are charming.

ELECTROCHEMISTRY IN BIOLOGY AND MEDICINE, edited by Theodore Shedlovsky. John Wiley & Sons, Inc. ($10.50). Electrochemistry provides methods for the study of many biologically important substances and factors, and it has made possible the analysis of structure and function of living cells, all of which are in fact complicated electrochemical systems "capable of transforming chemical energy and ionic transport into measurable electrical signals." In this valuable and interesting symposium 23 specialists describe various trends and aspects of contemporary electrochemical research, from the study of membranes to the examination of cardiac disorders, brain tumors and epilepsy.

THE EXPLORATION OF THE MOON, by Arthur C. Clarke and R. A. Smith. Harper & Brothers ($2.50). This book is a "step-by-step visualization" of the conquest of the moon. It describes the equipment, training, rocket launching, journey, landing and exploration, also the building of temporary and, later, permanent structures on the moon. In short, it tells you how to get there, stay a while and try to get back. Smith's drawings are mediocre and muddy; Clarke's text is clear, eager and not very convincing. On the whole, the trip 20,000 leagues under the sea with Captain Nemo in charge still seems a better bet.

WORLD RAILWAYS, edited by Henry Sampson. Rand McNally & Company ($25.00). This book is far less interesting than its companions, *Jane's Fighting Ships* and *Jane's All the World's Aircraft*. The illustrations are surprisingly sparse, their scope is historically inadequate, the text is strictly business in content, businesslike in tone. The third edition has been redesigned and revised to incorporate recent developments and trends in railroad transportation. It describes 1,500 railways in 108 countries, with maps and diagrams. New sections have been added on underground railways, motive power and rolling-stock manufacturers, Diesel engines, but unfortunately data on the older motive power and rolling stock have been eliminated. Of course no choo-choo buff can be without Sampson, but he will wish Sampson could unbend a little.

FLOODS, by William G. Hoyt and Walter B. Langbein. Princeton University Press ($7.50). A comprehensive and

scholarly monograph on floods in the U. S. The authors, associated for many years with the U. S. Geological Survey, discuss the genesis of floods, how they are measured, flood damage ($500 million yearly in the U. S. alone), flood zoning, insurance and forecasting, flood control policy, basin problems and projects, flood history and chronology. There are some 3,600 rivers, creeks, forks, runs, draws, washes, coulees, bayous, arroyos, inlets and hollows in the U. S. on which records are currently being collected. Bibliography, maps and photographs.

The Shaping of Our Alphabet, by Frank Denman. Alfred A. Knopf ($5.00). An attractive, effectively illustrated survey of the development of typography. Each chapter is set in a type face representative of the period under discussion. The book traces the evolution of typographic design from the beautiful incised Roman letters of Trajan's column through the Constance Missal and its successor, Gutenberg's Bible; the 19th century "fat face"; various ornamented Victorian horrors; unfortunate specimens of sans-serif modernism, and some of the more rational and handsome types of the present day. The author's attempt to relate changes of taste in typography to parallel changes in architecture, painting and other arts is perfunctory, but he tells the main story well.

America's Needs & Resources, by J. Frederic Dewhurst and Associates. The Twentieth Century Fund ($10.00). In this completely rewritten edition of a monumental economic survey first issued in 1947 the authors present an invaluable summary of America's present resources and future prospects. If the present rate of acceleration of productivity continues for a century, we shall be able to produce as much in a single seven-hour day as we do now in a 40-hour week. In 1960 our population will be about 177 million, our national product $414 billion, our average yearly income more than $6,000 per household. The U. S. now produces and consumes one third of the world's goods and services and nearly one half of the world's factory-produced goods. There are still millions of Americans who "have substandard housing, inadequate clothing, insufficient food, schooling, medical care and other basic requirements." Our resources in many raw materials are "running dangerously low" and as to many items—*e.g.*, tin, nickel, asbestos, graphite—we are entirely dependent on outside sources. But barring another war, and assuming we don't manage by various diplomatic capers to cut off the channels of international trade, most of us will be sitting prettier and prettier for some time to come.

EXCAVATIONS AT STAR CARR, by J. G. D. Clark. Cambridge University Press ($11.50). In 1947 traces were discovered of an early site (about 8000 B.C.) of Mesolithic hunter-fishers in the loop of an extinct river near the seaside resort of Scarborough in northeastern England. Systematic exploration of the site resulted in the discovery of rich archaeological deposits [see "A Stone Age Hunters' Camp," by Grahame Clark; SCIENTIFIC AMERICAN, May, 1952]. This handsome volume presents a full description, profusely illustrated, of the things dug up and of their significance.

Notes

A HISTORY OF THE WARFARE OF SCIENCE WITH THEOLOGY IN CHRISTENDOM, by Andrew D. White. George Braziller, Inc. ($5.00). It is gratifying to see the appearance of this reprint of a landmark of American literature by the distinguished champion of free thought and former president of Cornell University.

PROGRESS IN LOW TEMPERATURE PHYSICS, edited by C. J. Gorter. Interscience Publishers, Inc. ($8.75). Twenty-two contributors participate in a survey of recent research.

THE ATOM, by Sir George Thomson. Oxford University Press ($1.00). In the fourth edition of this attractive book in the Home University Library series, fresh matter has been added on mesons and other recent discoveries.

THE PREHISTORIC CULTURES OF THE HORN OF AFRICA, by J. Desmond Clark. Cambridge University Press ($18.50). The Curator of the Rhodes-Livingstone Museum of Northern Rhodesia reports on his archaeological findings in Somaliland. A pioneer contribution to the understanding of prehistoric industrial and cultural developments.

THE HISTORY AND CONQUEST OF COMMON DISEASES, edited by Walter R. Bett. University of Oklahoma Press ($4.00). An interesting cooperative work dealing with 17 types of diseases, from infections to malingering.

THE CHEMISTRY OF SYNTHETIC DYES AND PIGMENTS, edited by Herbert A. Lubs. Reinhold Publishing Corporation ($18.50). A comprehensive survey by 19 specialists.

THE AMATEUR SCIENTIST

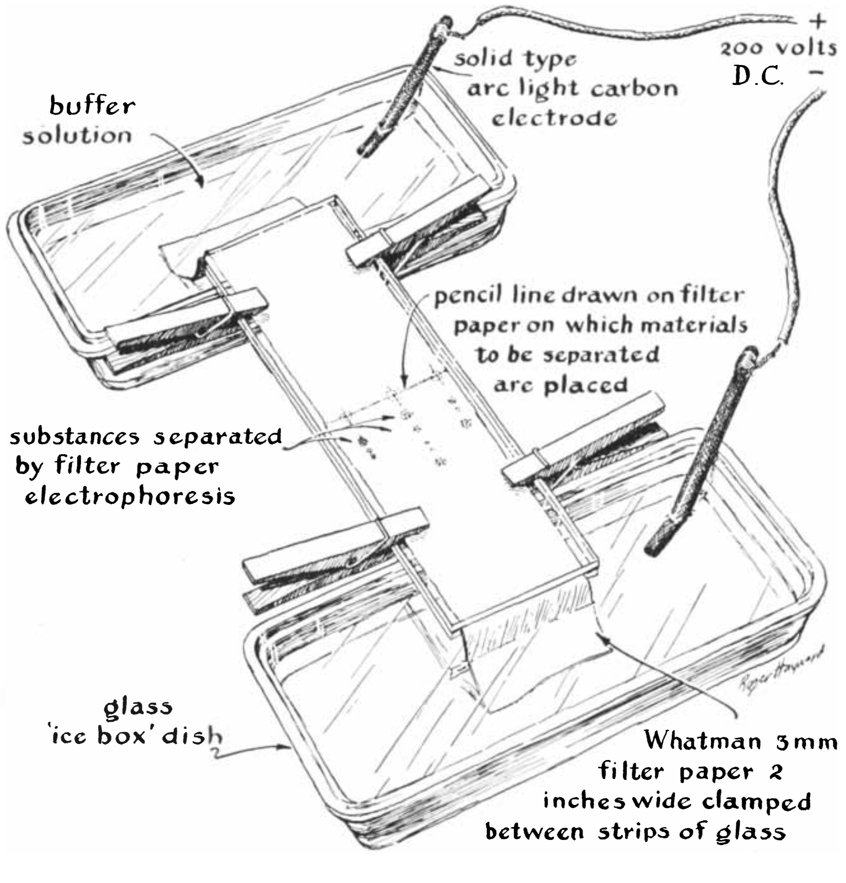
Concerning an electrophoresis apparatus to separate the components of a mixture

In February, 1953, this department told amateurs how to separate chemical mixtures by the process of chromatography. Many readers have since asked for a companion article on the equally fascinating technique of electrophoresis—the electrical method of sorting chemical mixtures. Unfortunately the elaborate electrophoresis apparatus invented by the Swedish chemist Arne Tiselius [see "Electrophoresis," by George W. Gray; SCIENTIFIC AMERICAN, December, 1951] is beyond amateur capabilities. Only a few hundred Tiselius instruments have been constructed, most of them by leading instrument makers or research institutions. Recently, however, a simplified technique known as "zone" electrophoresis has been devised. The following description of it has been made possible through the cooperation of H. G. Kunkel of the Rockefeller Institute for Medical Research. Anyone who enjoys experimental work and is willing to make a modest investment of cash and patience can quickly gain a measure of proficiency in the technique.

The word electrophoresis, as Gray pointed out, means "borne by electricity." In a broad sense the movement of charged pith balls in an electrostatic field is an electrophoretic effect. So is the Cottrell process for eliminating smoke particles from flue gases by passing them between electrodes of high potential difference. After picking up a charge from one electrode, the particles are attracted to the other, where they clump and fall into a collecting bin. The electrodeposition of colloidal rubber suspensions on electrodes of special shape—a process widely used in the manufacture of rubber gloves and other common articles—is another example.

But electrophoresis is the special name given to the technique of separating molecular mixtures into fractions. Most suspensions of molecules in water are charged and hence can conduct an electric current. Even molecules which normally do not carry a charge tend to adsorb ions from the water. Some molecules pick up more charge than others, depending upon their chemical nature and the concentration of ions in the solution. If the ionic concentration (pH) is properly adjusted, all closely related molecules, such as those of the proteins, appear to adsorb charges of the same sign. Consequently when they are subjected to an electric field they migrate in the same direction, although at rates which vary with the amount of charge on each member of the family. Many amateur microscopists have observed such migration on a gross scale with objects such as blood cells or protozoa. If a voltage is applied across a drop containing cells in suspension, the cells will migrate. Alexander Reuss first described the experiment 148 years ago, and it was a favorite of Michael Faraday.

To analyze molecular mixtures Tiselius hit upon a radically different scheme. He poured the material to be studied into the bottom of a U-shaped tube and carefully laid a buffered solution on top in each arm of the U so that sharp boundaries formed between the mixture and buffer. When a current was passed through the three-part solution, the material under analysis migrated down one arm of the U and up the other. Each of its fractions moved at a characteristic rate. The boundaries of each fraction were made visible by an elaboration of the schlieren optical technique devised

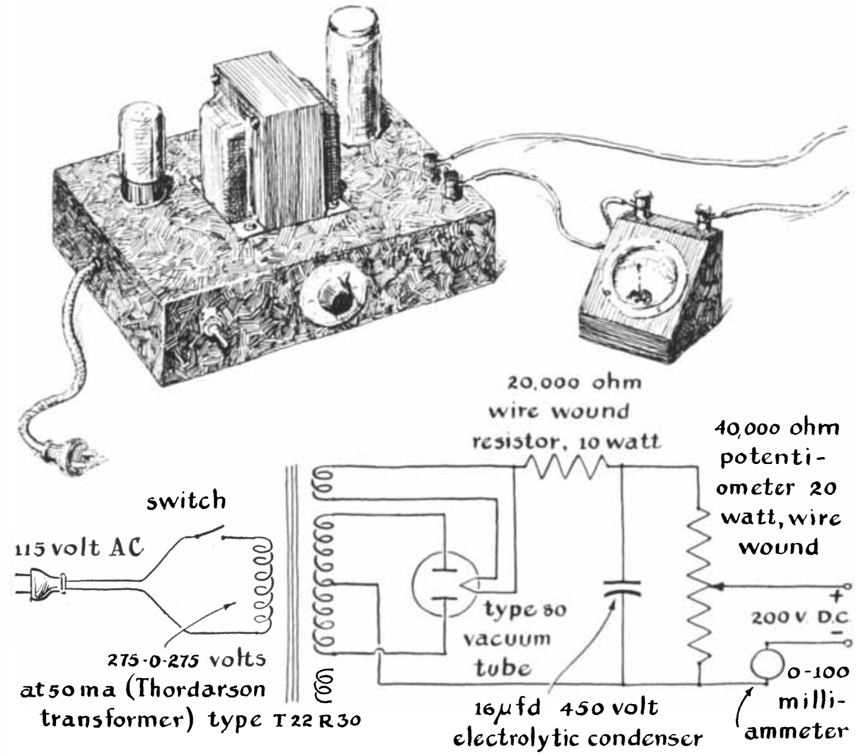


An amateur's zone electrophoresis apparatus by Léon Foucault for testing the figure of parabolic mirrors and lenses. Like the ruling engine for making diffraction gratings, the Tiselius technique of "free" electrophoresis is simple in principle. Like the ruling engine, too, the method appears easy until you set up the apparatus and try to make it work! In this domain the gifted professional appears safe from amateur challenge.

The less precise yet powerful method of zone electrophoresis has found wide application during the past five years. In the zone method, particles move in liquid that fills the spaces of a finely divided solid instead of a U-tube. Molecules of like kind migrate as distinct zones which can easily be identified and recovered as purified products. Porous solids of many kinds can serve as the medium. One medium frequently used is filter paper. Zone electrophoresis thus bears a superficial resemblance to partition chromatography. The electrophoretic separation, however, depends not upon the properties of solubility and adsorption, as in the case of chromatography, but upon the electrical charge carried by the molecules of the substance that is being analyzed.

The amount and sign of the charge picked up by compounds in solution depend both upon the chemical nature of the compound and upon the pH of the solvent. Molecules which normally carry a weak charge, such as the slightly alkaline proteins, are highly sensitive to changes in pH. A small shift in acidity or alkalinity can cause a substantial change in the rate at which such particles migrate and may even reverse the direction of their movement. One therefore selects for the solution electrolytes (sources of charge) which have a "buffering" action: that is, which tend to supply positive and negative ions to the solution at a rate precisely offsetting that at which ions are removed or dissipated. Many common salts have a strong buffering action, although table salt (sodium chloride) is not one of them.

Unfortunately there are no textbooks on electrophoresis, and most of the literature is confined to biological and medical journals not readily available. Hence an amateur who takes up electrophoresis will have to find his way through woods where few trees are blazed. Except for protein chemistry, he must develop his own electrolytes, buffers and solid media, and must find out by experiment just what voltages and current densities work best for the substance under analysis. The field of electrophoresis has barely been scratched. If you enjoy original work, you can dig in almost anywhere,



Power supply for zone electrophoresis

certain that you are breaking fresh ground.

To give you a start, we picture here the essentials of an apparatus which uses filter paper as the solid medium [*drawing on page 92*]. You can set it up and put it into operation in a single evening.

The ends of the paper dip into two vessels containing an electrolytic solution connected through carbon electrodes to a source of direct current. To retard evaporation of the solution from the paper, we sandwich it within a pair of glass plates. The plates, about two inches wide and eight inches long, are cut from window glass. As a safety precaution it is a good idea to round the edges and corners of the glass on either a whetstone (using water as a lubricant) or on a sheet of glass smeared with a slurry of carborundum.

It is desirable to maintain an even pressure of the glass on the filter paper, so that migration proceeds in a symmetrical and reproducible pattern. Pressure improves the sharpness of the zones, because it reduces the amount of fluid in the paper. However, if the pressure is too high, it will bend the glass and distort the zones. Some workers have attempted to solve the problem by using plates an inch or more thick. The bottom plate is supported by a flat base and the top one rests on the paper as a weight. Others suspend the paper from glass rods laid across the buffer vessels. The apparatus is then covered by a bell jar and operated in a buffer-saturated atmosphere. The latter method has the disadvantage that the buffer tends to gravitate toward the low point of the strip with consequent distortion of the pattern of separation.

Capillary effects between the glass plates and the paper also introduce some distortion. This is minimized by coating the plates with a film of grease. Vaseline will work, but not so well as silicone grease of the type used for lubricating the stopcocks of chemical glassware.

Glass containers of any convenient shape can be used as buffer vessels. Heavy pyrex icebox dishes, available from hardware dealers, work as well as specially made glassware. The principal considerations in the selection of containers are chemical inertness and enough weight so the empty vessels will support the plates, paper strip and clamps without upsetting.

Chemical inertness is a major consideration in the choice of electrodes. Most professionals use platinum, but carbon rods work almost as well. Avoid the cored carbons used in sun lamps. These cores are charged with finely divided metal (to enrich the emission of ultraviolet rays) and will contaminate the solution. Solid carbons designed for low-intensity motion-picture projectors are good and can be procured from theater-supply dealers.

The amount of electric current needed varies with the substance under analysis. A rectifier capable of operating between 50 and 300 volts at an output of 20 milliamperes will be ample for most work. You may get a good rectifier from a junked radio receiver. Just connect a 40,000-ohm wire-wound resistor (of the type fitted with an adjustable tap) across the filter condenser. The resistor should be of at least the 20-watt size. Take the output from across the ground side of the resistor and the tap. If no old radio set is at hand, you can get the parts specified in the drawing [*opposite page*] from radio supply dealers.

It is frequently desirable, particularly during the experimental phase of analyzing unknown substances, to maintain either a constant voltage across the paper strip or a constant current through it. Power supplies with automatic regulating features can be constructed, but they are costly and complex. Good results can be achieved with a manual control. Substituting a continuously variable potentiometer for the tapped resistor makes adjustment easy, and the knob will protect your fingers from the hot resistance element.

Almost any soft paper will demonstrate zone electrophoresis. You can use strips cut from white blotters, paper towels, cleansing tissues, even the unprinted parts of old newspapers. Clear, reproducible patterns, however, require a specially made paper of uniform texture and free of contamination. A good paper is Whatman 3MM, supplied in 600-foot rolls by the Fisher Scientific Company of New York City, which also has most of the chemicals used in electrophoresis experiments. You can order the Fisher materials at drug stores.

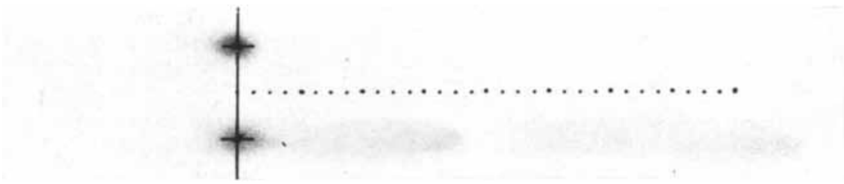
The separation of the artificial coloring used in a cheap wine is a nice electrophoretic project for a beginner. You can make your own mixture for analysis by adding a few drops of food coloring to grape juice. For an electrolyte you can use a weak solution of common salt buffered with a small amount of baking soda (sodium bicarbonate). Later you can investigate electrolytes made with other salts, many of which provide their own buffering action.

Food coloring migrates nicely in an electric field of 25 volts per inch at a current of 10 milliamperes. This means that the buffer-moistened filter paper should have a resistance of about 2,500 ohms. To obtain this value of resistance you will have to experiment with various dilutions of the electrolyte. Begin by drawing enough tap water to fill the icebox dishes to within half an inch of the top. Put all this water in one container and add a level teaspoon of salt. After it dissolves, immerse the paper strip in the solution. Remove the strip, blot it thoroughly and clamp it between the glass plates. Then pour the solution into the icebox dishes, suspend the ends of the paper in it [*drawing on page 92*], connect the power supply to the solution through the carbon electrodes and adjust the potentiometer or tapped resistor to the prescribed potential of 200 volts.

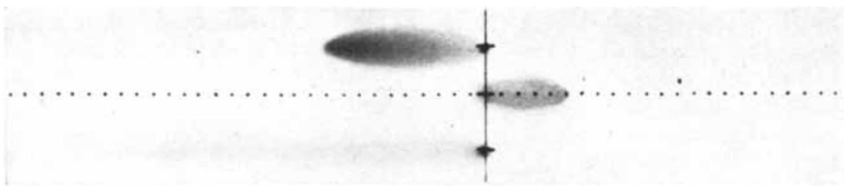
If the resulting current is less than 10 milliamperes, turn off the power, remove the strip, return the solution to the common container, add more salt and try again. Usually a level teaspoon of salt for each 12 ounces of water produces the desired conductivity, but the amount needed varies with the purity of the tap water. Finally add a quarter teaspoon of baking soda for each 12 ounces of solution. (It will affect the resistance only slightly.)

After you have an electrolyte with the proper resistance, draw a light pencil line across the middle of a fresh strip of filter paper, dip the strip into the buffered

Imported Chianti (top) *and an inexpensive domestic Chianti* (bottom) *are analyzed*



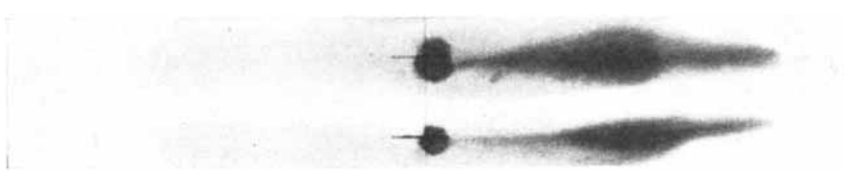
Pure grape juice (top) *and grape juice colored with dyes* (bottom) *are compared*



The migration of methylene blue (top), *eosin Y* (middle) *and basic fuchsin* (bottom)

The pattern of blood proteins from a normal individual

The pattern of blood proteins from an individual suffering from myeloma



An amateur's first attempt to fractionate the white of an egg electrolyte, blot it and then apply a drop of wine to the pencil line with the blunt end of a toothpick. The wine should first be concentrated by letting it evaporate at room temperature to half or less of its normal volume. Now spread a film of grease on the inner faces of the glass plates. Clamp the paper between them, seal the edges of the plates with grease, immerse the protruding ends of the paper into the buffer and switch on the power.

If the wine sample contains artificial coloring, in about five minutes the edge of the wine spot nearest the anode should become sharper and the edge toward the cathode should grow fuzzier. Within an hour a blotch of dye, probably comet-shaped, will have migrated a substantial distance from the point of origin. As the process continues, comets of other colors, each a constituent of the dye, will trail the first one down the length of the paper [*see top pattern on the opposite page*]. The dye fractions in the wine should be fully resolved in about six hours. (The blotch made by the wine itself will move little, if at all.) By spacing drops along the pencil line you can analyze several samples of fluid simultaneously on the same strip of paper.

The tendency of zones to smear, trail, assume comet shapes and otherwise depart from sharpness is one of the undesirable features of zone electrophoresis on filter paper. It represents a challenge to the experimenter. In general the drier you can run the filter paper (or other solid medium), the sharper the zones will be. Within limits dryness can be achieved by applying heavy pressure on the glass plates: in effect you try to squeeze out the buffer. The spots should be dry enough so that you can rub your hand across the paper as it comes from the apparatus at the end of a run without smearing the pattern. The amateur who resolves the dilemma of applying enough pressure without bending the glass will make a contribution to science.

Substances which migrate more rapidly than others along the electrophoretic paper are said to have "high mobility." Mobility is determined in large part by the strength of ionization of the particles. Measuring the mobility of substances is an interesting project for beginners. You simply time the rate of migration of each substance along a scale ruled on the strip of paper, using a control buffer of a certain pH and concentration. Stains used for coloring organisms to show them under the microscope make nice test specimens. A particularly good series is eosin Y, methylene blue, basic fuchsin, malachite green, Bismarck brown, safranine and gentian violet. The chemical properties of these stains are listed in reference texts. Each migrates in a saline solution at a characteristic rate. The third pattern from the top on page 96 shows the relative migration rates of positively ionized methylene blue (*top*) and basic fuchsin (*bottom*), and negatively ionized eosin Y (*middle*). These were resolved on filter paper with a saline solution buffered with sodium bicarbonate. The same test showed that the malachite green stain migrates an inch per hour at 70 degrees Fahrenheit under 200 volts and 10 milliamperes.

Amateurs who wish to have a go at something more sophisticated may enjoy trying to separate blood proteins. This entails the sacrifice of a few drops of blood. You will also need access to a centrifuge (to extract the serum from the blood), a few grams of the barbiturate veronal and a liter of 95 per cent ethyl alcohol.

Dampen the filter paper with barbital buffer adjusted to pH 8.6. After blotting the paper, deposit five thousandths of a milliliter of serum on the ruled strip with a calibrated micropipette. Then clamp the paper between the plates and seal it with silicone grease.

A potential of 15 volts per centimeter and a current of 15 milliamperes will resolve a specimen in five or six hours; however, the pattern may show traces of smearing. Four volts per centimeter and four milliamperes increases the time to 12 hours but yields sharper patterns. Blood-serum fractions are difficult to see. The albumin can be made more strikingly visible by labeling it with a few crystals of bromphenol blue. After the albumin has migrated an arbitrary distance, say seven centimeters, the paper is removed and dipped for two minutes into a solution of 95 per cent ethyl alcohol saturated with mercuric chloride, to which 1 per cent bromphenol blue is added. The strip will emerge from the stain a deep yellow. It is then washed repeatedly in water containing a thousandth part of acetic acid. On contact with water, the yellow changes to a deep blue. The color gradually disappears from the paper during washing but is retained by the protein fractions. The fourth and fifth patterns from the top on page 96 show typical separations of blood proteins taken from two individuals, one in normal health and the other diseased. The density of the spots in each pattern indicates the amount of protein in each fraction. From right to left the fourth pattern (normal serum) shows albumin, alpha-one globulin, alpha-two globulin, beta globulin and gamma globulin. The dense spot at the left in the fifth pattern is characteristic of the bone disease myeloma. Other diseases produce characteristic patterns which serve as valuable aids in diagnosis.

The result of an amateur's first attempt to fractionate albumin (the white of chicken egg) is shown in the bottom pattern on page 96. The smeared pattern explains this experimenter's passion for anonymity. Here the buffer was salt, baking soda and water.

A number of techniques have been devised for making quantitative measurements of protein patterns. In one the strip is sectioned into eighth-inch segments. The dye in each is then quantitatively eluted in a two milliliter solution of 1 per cent N-sodium hydroxide and read, after an hour or so, on a colorimeter. The resulting values are plotted as points. The smooth curve drawn through them is equivalent to the curve derived by free electrophoresis.

As mentioned earlier, zone electrophoresis is not limited to filter paper. It is interesting to compare the behavior of a given test substance and buffer in media compounded of starch grains, silica gel, activated alumina and similar materials, as well as the reaction of various buffers with respect to a given medium. A slab of starch, for example, is easy to prepare. Put a pound of potato starch into a sieve lined with filter paper. Wash the starch for 30 minutes and pour it as a batter into a rectangular mold. The slab (about ⅜-inch thick) is then thoroughly blotted, and with suitable carbon electrodes it can be used in principle just like filter paper. The only limit to variations in the physical arrangement of the apparatus is set by the ingenuity of the worker. It is possible, for example, to adapt electrophoresis for the continuous separation of material in gross amounts. At least one amateur telescope maker prepares colloidal rouge by means of continuous electrophoretic separation. Buffer is allowed to flow down a wide strip of filter paper by capillary attraction. It drips from the bottom edge of the paper into a container below. The rouge mixture is fed onto the paper from a continuously flowing micropipette near the top. Electrical contact is made with the edges of the strip through wicks saturated by buffer. Fractions not ionized flow down the strip vertically. Ionized fractions take a diagonal course, the steepness of which depends upon the strength of the ionization. A scallop is cut into the bottom of the strip in line with each fraction, and collecting vessels are placed beneath the points. The collected fractions are then purified.

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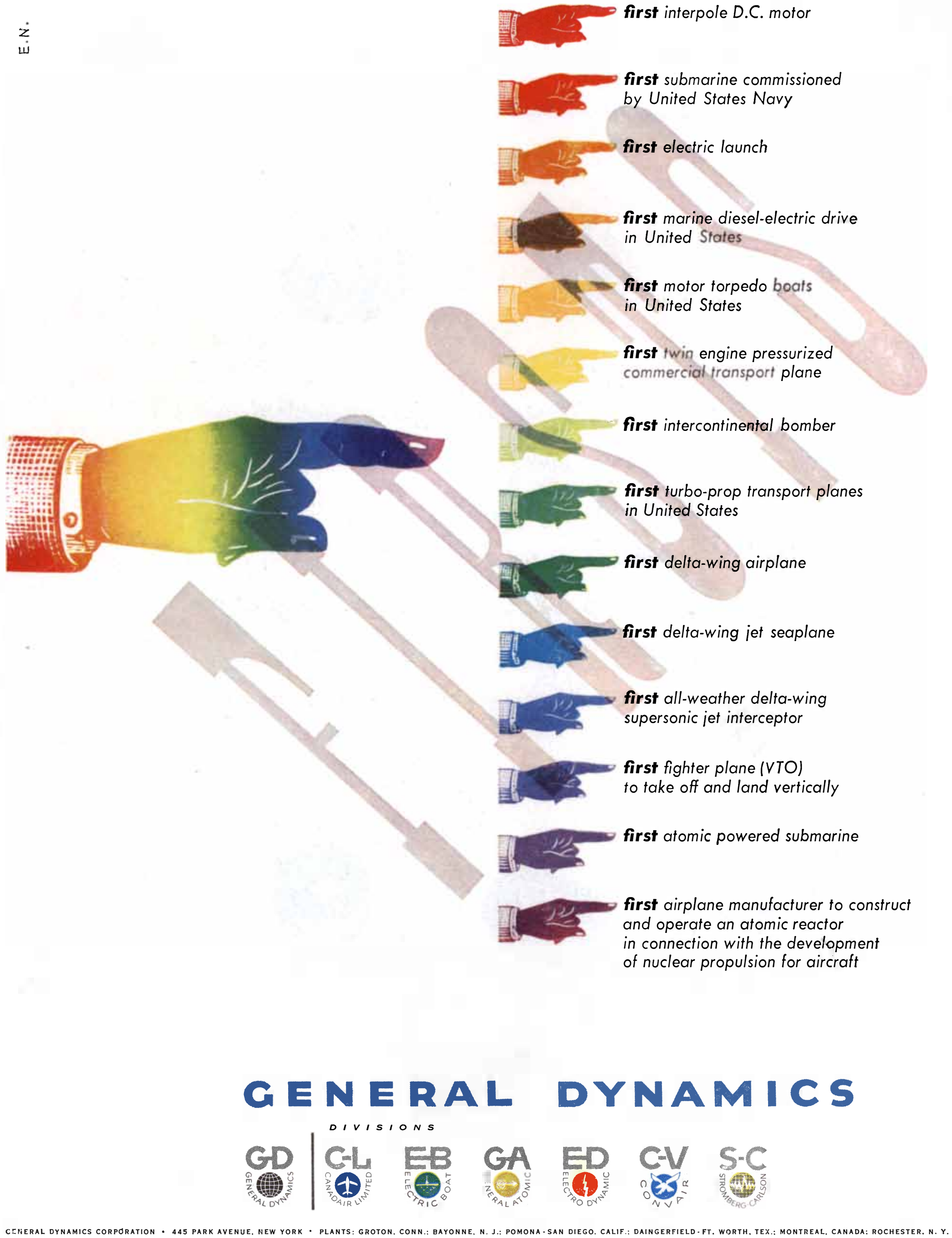
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