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August 1957

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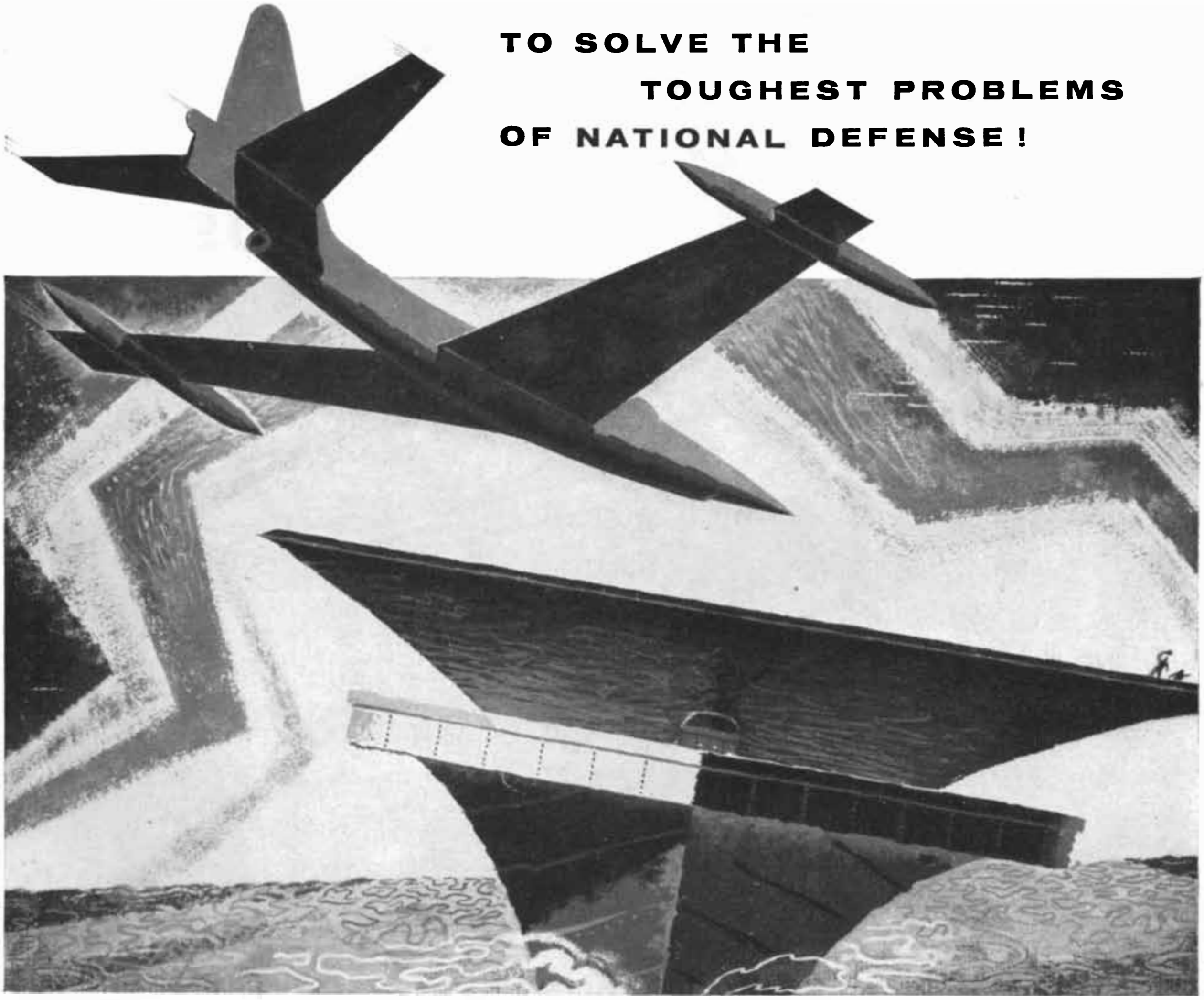

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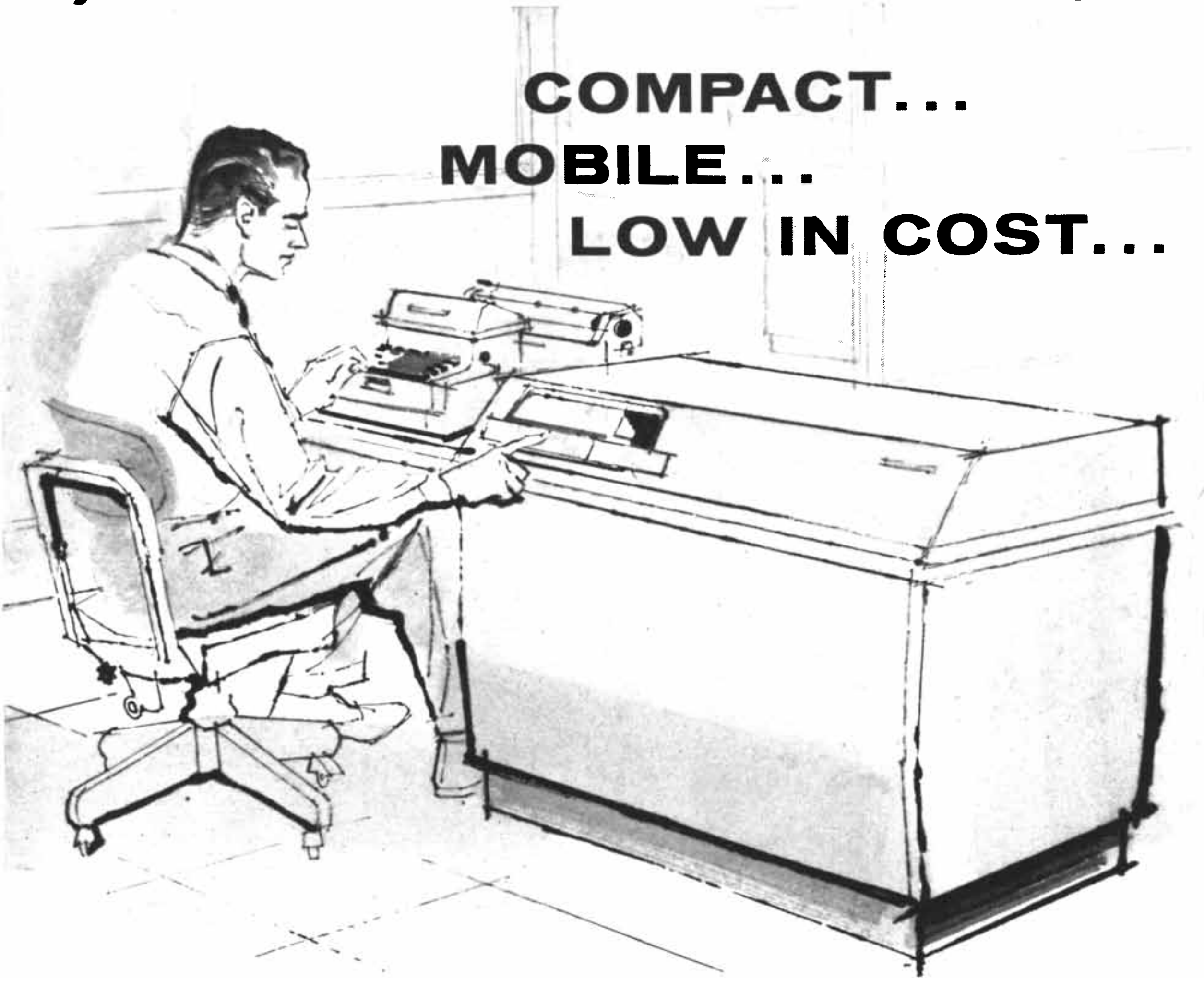

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Established 1845 **SCIENTIFIC AMERICAN** August, 1957 Volume 197 Number 2

ARTICLES

DEPARTMENTS

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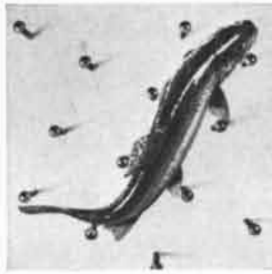

THE COVER

The painting on the cover shows a trout against a board covered with pegs. As the highlight on the back of the fish indicates, the trout is not in the water but out of it. The trout was placed on the board as part of a study at the University of Cambridge on how fishes swim (*page 48*).

THE ILLUSTRATIONS

Cover painting by Rudolf Freund

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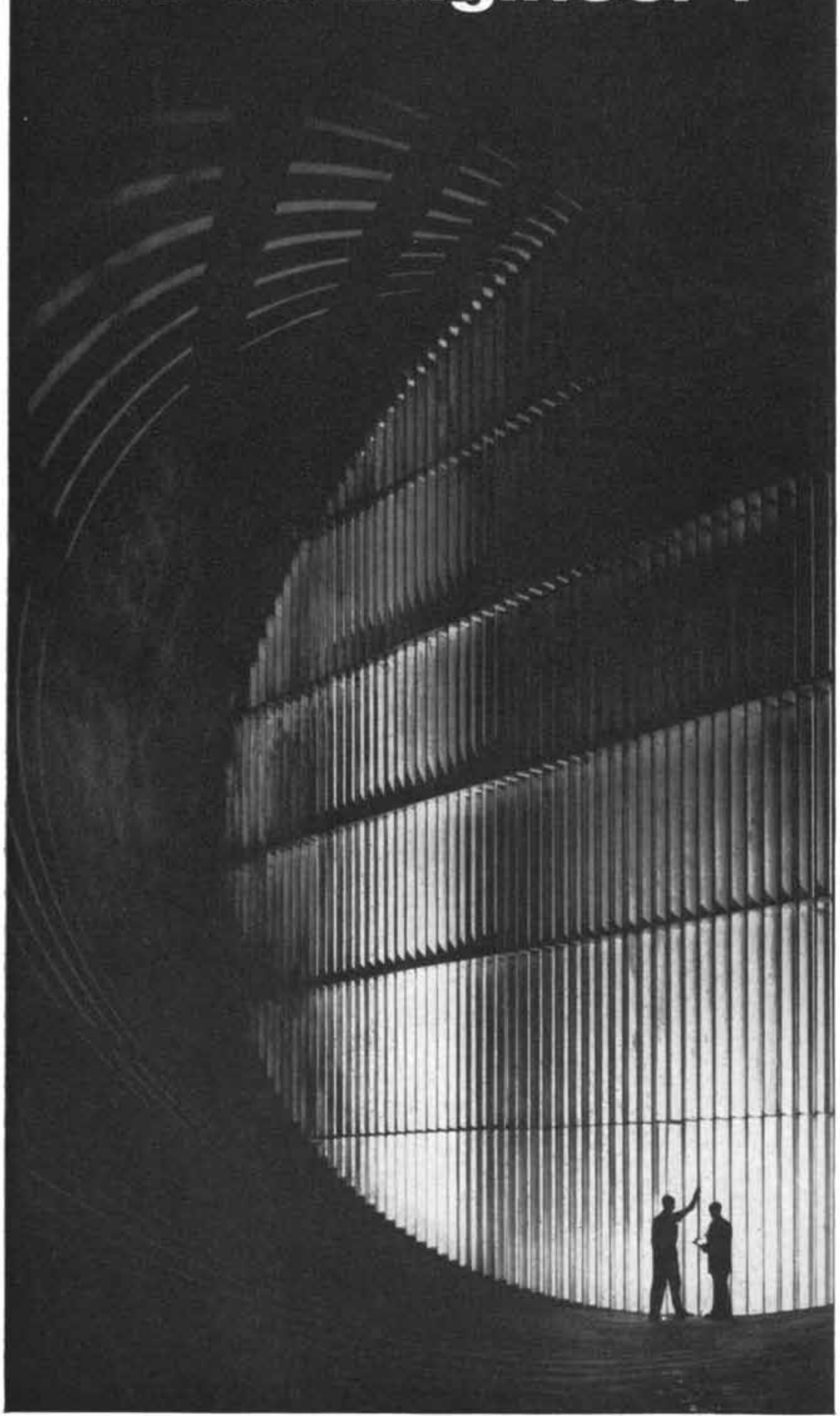
The 26th in a Series of Advertisements Presented by New York Life to Help Guide America's Children to a Better Future

Should your child be an Engineer?



Against the backdrop of the NACA transonic wind tunnel at Langley Field, Virginia, stand two young engineers. The abstract patterns seem to symbolize the dramatic role played by today's engineer in the never-ending drive toward technological progress. It is he who translates dreaming into doing . . . he to whom the future promises its greatest challenge.

by T. Keith Glennan

President of Case Institute of Technology, Cleveland, Ohio

(As told to OSCAR SCHISGALL)

HUNDREDS OF THEM, all engineers, had gathered for their fifth annual alumni reunion. There was the usual exuberance of shoulder-thumping and hand-shaking, with everybody saying to everybody else, "You old so-and-so, what are you *doing* these days?"

I wandered from one cheerful group to another, and here are some of the answers I caught:

"I'm out on the desert. Missile testing outfit."

"I'm laying out a shoe factory in Binghamton, New York."

"I'm down in Maracaibo. Drilling for oil under the sea."

"I'm in the research lab of an Ohio plastics plant."

"I'm with a dredging outfit. Widening a river channel."

"I'm with a TV company. Working on color."

"I'm in construction. We're putting up two Park Avenue skyscrapers in New York."

"I'm in air conditioning."

"I'm in ceramics. Developing new kinds of building materials."

So it went: never the same answer twice. And this was revealing.

Only a few years ago the question, "Should your child be an engineer?" would evoke the image of a young man signaling from a tripod in midstreet; or perhaps of an older man supervising the construction of a bridge. I suppose these visualizations are still valid. But if you plan to consider the work of an engineer in our time, you will have to picture him in hundreds of different roles. For the word "engineer" has come to mean almost as many different occupations as there are industries.

Certainly the engineer who works on aircraft design is hardly the same fellow who, as an industrial engineer, builds a vast new conveyor system into an automotive plant; nor has he much in common with the chemical engineer, the nuclear engineer, or any of the other scores upon scores of engineering specialists I could name.

Believe it or not, there are more than 150 different organizations of American engineers, each devoted to its own specialized interest!

So when we ask today, "Should your child be an engineer?" we are really asking whether he should be a trained expert in some aspect of modern technology.

The scientists and engineers have become key figures in our modern industrial society. And this is only the dawn of their heyday. Scientific progress is constantly opening up new horizons, bringing new needs, new opportunities. In this era of mass production there is virtually no industry which does not require the skills and services of engineers.

Food? The growth of the frozen food business, as an example, has created countless demands for engineering know-how. Better methods of refrigeration in transit, better ways of storing and freezing at home—these and other improvements all depend on the ingenuity of engineers.

Clothing? The development of synthetic fabrics has brought new challenges and new opportunities to chemical engineers. Chemistry has, in fact, become one of the most important factors in the giant textile industry, producing countless new plants and thousands of new jobs.

Homes? Modern techniques not only in building and in architecture, but in heating, in air conditioning, in every aspect of electrification—all these call for the skill of engineers.

Communications? Without engineers there would be no television, no radio, no telephones, no telegraph lines, no cables.

"In this era of technology," I have heard it said, "engineering furnishes the basic training for almost any industrial career you can mention." And that is emphatically true.

People often ask me what is included in an academic program leading to a degree in engineering. They ask, "Isn't an engineering course basically a narrow one?" The answer, of course, is that the modern engineering curricula are so constructed as to provide an excellent and quite broad preparation for an effective life in a technological society such as ours.

Mathematics, physics, and chemistry are still the bedrock courses for the future engineer; without them he cannot go very far. The more of them he can get during his high school and college years, the better. But these must be regarded only as a beginning.

The fact that future engineers will enter every walk of life makes it necessary for these students to have, in addition to concentration in the natural sciences and the art and practice of engineering, a fine liberal education in the humanities. I am happy to say that most of our great institutes of technology and engineering colleges have recognized this. They have broadened their curricula to include substantial blocks of time for studies in the humanities and social sciences.

Naturally, what most young people want to know about engineering is this: Is it a good profession? Does it pay well? Does it offer wide opportunities for creative activity and for responsible leadership?

Frankly, I know of no profession that offers more today.

Look at the advertisements in our metropolitan newspapers. I do not mean only the classified help-wanted columns; I mean the big display ads inserted by countless firms that employ engineers. They plead with engineering students to come for interviews and conferences. They hang out the inducements of good pay (including such fringe benefits as retirement plans and group insurance), and good living conditions. Never before, as far back as I can remember, has industry competed so militantly for the services of young engineers.

As a result of this demand, no matter what branch of work the graduate of an engineering college may enter, he can count on earning at least $5,000 a year to start. Some men who are trained in specialties or who are willing to travel will command even higher salaries.

Moreover, the man with a master's degree can begin at $7,500; and a Ph.D. can easily earn $9,000.

And what is the limit on earnings? There is no limit except ability and willingness to accept responsibility. Increasingly, in this age of technology, the engineer is being called on to assume top supervisory and managerial jobs in his own and allied fields. When he reaches executive levels the engineer can go to any figure—salaries of $35,000 and more are no longer uncommon.

Probably no single field offers a broader choice of occupation than engineering. Every industry from steelmaking to papermaking, every locale from offshore drilling rig to city skyscraper can hold an assignment for the graduate engineer.

Another point to remember: Though I have no wish to be an alarmist, I must emphasize the fact that our country is competing against communist Russia for leadership, not only in such areas as aviation, atomic weapon development, and guided missiles, but also in almost every type of commercial production, including the peaceful use of the atom. So our national future may well depend on the quality and the number of our engineers. *And Russian schools are reported to be graduating approximately double the number of new engineers that ours are.*

This is a point to ponder soberly when thinking of a career. We in America need every engineer we can produce.

That brings up the question of women in the profession. Until now women have played a quiet role in engineering. For the most part they have served as laboratory technicians and research assistants. But I believe this is bound to change.

Recently the National Society of Professional Engineers queried several hundred leading firms on their attitude toward employing women engineers. The replies indicated that 65% of the firms would gladly hire women if they were available; and 23% of them already have women on their staffs.

Perhaps the future is brighter than women realize.

How long will the present demand for engineers continue? The need will go on, I believe, for generations. Our population is constantly increasing. By the end of the century we will probably be a nation of over 200,000,000. This growth, especially in a technological era which almost daily provides new ideas and new machines, will require more and more engineers. They are the most widely needed servants of such an age.

Also, our defense program seems destined to continue indefinitely. This means a great number of engineers must devote their time to research, planning, and development in connection with our military arsenal. As a result, there will continue to be a scarcity of engineering talent to meet the demands of private industry.

So when one asks, "Should my child be an engineer?" one can be sure that engineers are *needed* today and that their opportunities will be widespread and alluring.

What must be considered is not so much the attractions of the profession—these exist in abundance—but rather the skills, the aptitudes, the likes of the child.

If a youngster's great love is music, for example, one need hardly argue the point that he should follow a musical career. The first criterion to consider is:

Does the child have a natural aptitude for the sciences?

Does he love to cope with the challenge that a scientific problem tosses at his imagination?

Is he skillful in mathematics, physics, chemistry?

Is the science department of his school the one to which he naturally gravitates?

Are his extra-curricular activities apt to lie with science clubs and similar experimental groups?

Does he love to read about scientific advances?

These are the considerations to be weighed. If a child meets the test of such questions with affirmatives on the side of science, then the chances are he will find engineering a satisfying, rewarding and always adventurous career.

HOW TO HELP YOUR CHILD HAVE THE CAREER HE WANTS

Many factors will enter into your child's choice of a career: his interests, his ambitions, his abilities, the counsel he receives from teachers, friends and family. But, most of all, it will depend on his opportunities *to get the training he needs to enter the field of his choice.*

Even though his college days are still years away, it's never too soon to start making sure that your child will have the opportunity to continue his education when the time comes.

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LETTERS

Sirs:

I was very much interested in George A. Llano's article "Sharks *v.* Men" in the June issue of *Scientific American.* However, I believe that if you doubled the figures given by Llano, you would come closer to the actual number of attacks by sharks. For example, this year a friend of mine bathing at Fort Pierce, Fla., was badly mauled by a five-foot shark in about 2½ feet of water. The same thing occurred last year at Vero Beach and the previous year two more attacks occurred farther north. It would seem that the states of South Carolina, Georgia and Florida, by virtue of their tourist trade, are not anxious to report these attacks.

A further observation on the 1916 invasion of sharks along the upper Atlantic coast: That year had a very warm spring and a warm and extremely humid summer. The same summer numerous sharks were noted close to the shore at Watch Hill, R.I., and along the shore of Connecticut. While there were no fatalities reported, there were many attacks of a minor or semiserious nature.

It would seem that it is very hard to get precise information on sharks attacking man unless the attacks are fatal. Fatalities must of course be reported by the medical examiner.

RAYMOND NAUTH, E.E., PH.D.

Administrator
Detroit Engineering Institute
Detroit, Mich.

Sirs:

Dr. Nauth's remarks on the matter of precise information on shark assaults, and especially those causing minor injuries, are very pertinent. With increasing numbers of our swelling population turning to the sea for recreation, the probability of a rise in shark assaults is not to be ignored. Under these circumstances, it would repay those with vested interests in seashore property to approach the problem with intelligence and, by keeping a more accurate record of these incidents, be in a position to deal more realistically with the hazard. American city fathers might well take a lesson from Sydney and other Australian coastal towns where shark attacks are dealt with in a systematic and open manner. The Australian authority V. M. Coppleson describes the effectiveness of various techniques in his forthcoming book *Shark Attack.*

Dr. Nauth's report of other Florida incidents are undoubtedly true and might well double the incidence of attacks for this region. However, each report must be documented, and this brings up the matter of authenticity. Since the medical examiner has the last word, as Dr. Nauth has observed, I made a search of the medical literature through *Index Medicus*, *Current List of Medical Literature* and *Index Catalogus of the Surgeon General's Office.* Case histories from these sources, although reliable, are few in number. The lay literature was surveyed by using *Poole's Index*, *Reader's Guide to Periodical Literature* and similar sources, but here one enters the realm of the professional writer who cannot resist improving on a good story. Still seeking specific facts and a broader coverage, I turned to the New York *Times* and the London *Times* and found not only details but summaries of topical interest. The facts which are essential to the authenticity of an incident are, specifically, reference to an individual by name, address and age; locality; the time and date of the attack; the nature of the injuries. This evidence was presented in my article as "documented" when given by medical authority, and "reported" when substantiated by newspaper accounts. It would be desirable to check local newspapers of southern resort areas for minor incidents, which are not always reported in the larger city dailies, but this is difficult.

A point which needs further clarifica-

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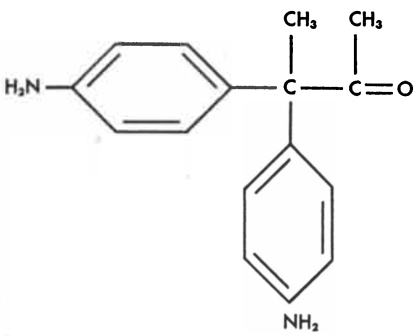
tion is the relationship between invasion of sharks and weather. Changes in the path of the Gulf Stream and subsequent variations in water temperature are known to cause the destruction of many fish. Such mass destruction would undoubtedly attract scavengers. Later, while the fish population is building up to normal, food would be at a premium and in that event sharks might be forced to invade shallower waters in quest of prey. This phenomenon might coincide with the sporadic appearance of sharks along the Atlantic coast. But insofar as I have been able to determine there are no data available for extrapolation and predictability which would be useful in forecasting the probable advent of sharks along our coasts. For my part, I should welcome any information on shark incidents known to readers of *Scientific American.*

GEORGE A. LLANO

Arctic, Desert, Tropic Information Center
Research Studies Institute
Air University
Maxwell Air Force Base, Ala.

Sirs:

Some of your readers may be interested to know that the structure of amphenone B, given in your article "Hormones," by Sir Solly Zuckerman, and taken from the publication of Allen and Corwin in *Journal of the American Chemical Society,* Vol. 72, No. 117 (1950) has been revised to:

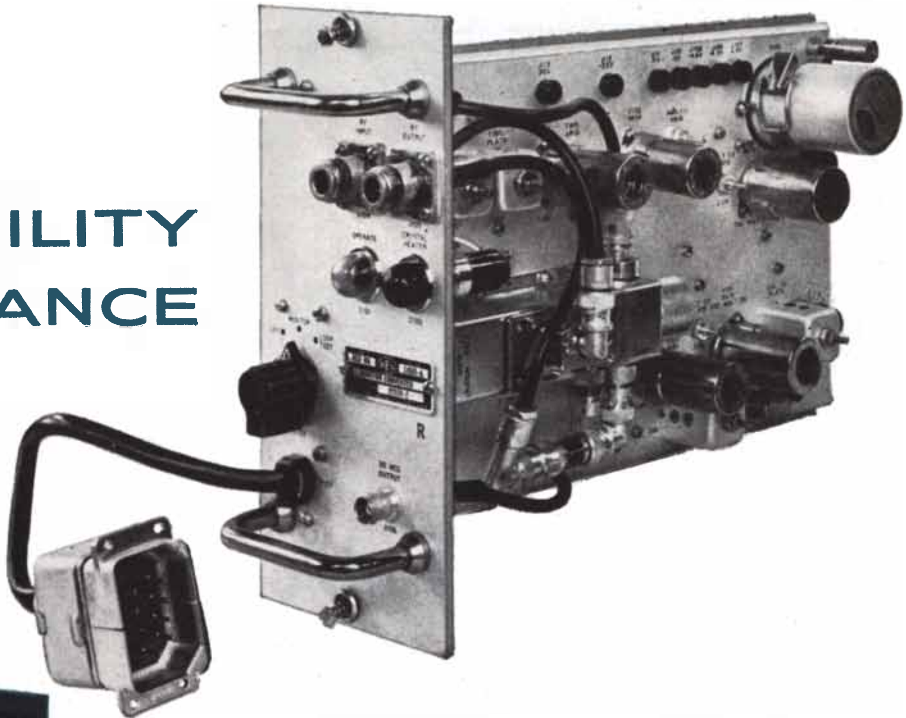


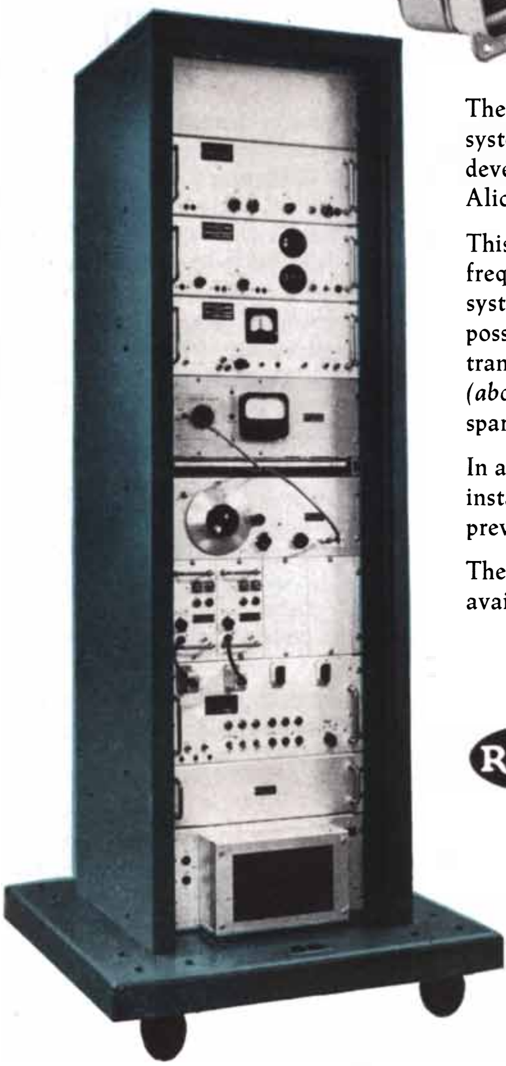
This is according to the paper published by Bencze and Allen in *Journal of Organic Chemistry,* Vol. 22, No. 352 (1957).

MILTON J. ALLEN

Director
Physical Research Laboratories
Ciba Pharmaceutical Products, Inc.
Summit, N.J.

RELIABILITY ASSURANCE





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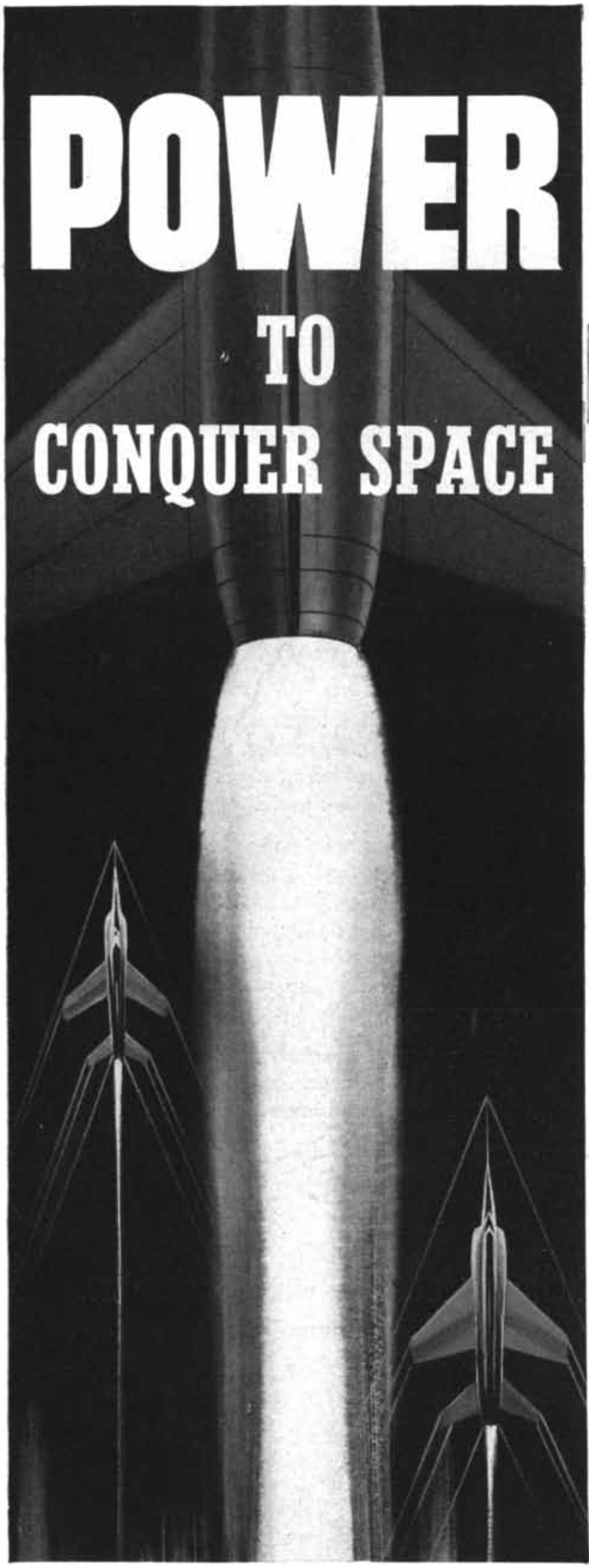

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Life on the Chemical Newsfront

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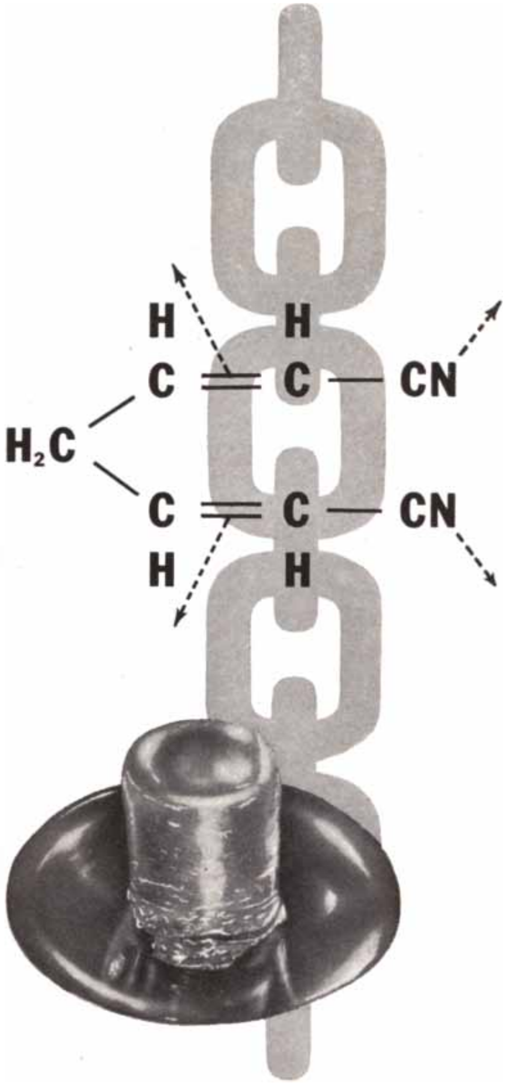
(Industrial Chemicals Division, Dept. A)

NEW PIPE JACKET COMBATS UNDERGROUND CORROSION. Strong jackets of spirally-wrapped glass cloth and LAMINAC® Polyester Resin combat corrosion of pipe in new prefabricated insulated conduit for underground steam and hot-water systems. The protective two-ply shell is much lighter, less costly and more corrosion-resistant than conventional steel or tar-protected conduit. Insulation is sealed and vapor-proofed at the ends by bonding the cloth-resin shell directly to the bare pipe. Field joints are easily applied at the site. **(Plastics and Resins Division)**



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(New Product Development, Dept. A)

†Available from Petrochemicals Department

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(Organic Chemicals Division)

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SCIENTIFIC AMERICAN

AUGUST, 1907: "Sir William Ramsay has recently made an announcement which, coming from so high a source, must be treated with respect and which, if borne out, must rank with his famous discovery of the transformation of radium emanation into helium. He states that after long experimenting with the effect of various combinations brought into contact with radium emanation, he has observed that copper compounds are transmuted or 'degraded,' in his own words, to lithium. After a solution of copper phosphate has been treated with the emanation and the copper then removed, the spectrum of the residue exhibits the red line of lithium."

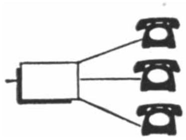
"Wireless telegraphy now appears to be settling down on a practical basis. It is finding its important field to be where all those who have not been actuated by interested motives have consistently stated it would be found—namely, as a means of communication between ships at sea and between ships and the shore. How long it will hold this field undisputed depends upon the measure of success that may attend the efforts of those who are now endeavoring to perfect wireless telephony. Probably one of the chief reasons why wireless telegraphy is not already universally installed on all manner of sailing vessels and steamships is the necessity for employing an expert Morse operator to transmit and receive messages."

"Twenty-five knots has for some time been recognized as the maximum speed which, in the present condition of the shipbuilders' art, it would be possible to secure in a big ocean steamship. Indeed, it was only when the marine steam turbine began to reveal its possibilities that the creation of a 25-knot liner began to take shape in the mind of the naval architect. Congratulations are due the Cunard Steamship Company, as being the first to place in service a ship of this maximum speed, particularly when it is borne in mind that to the distinction of

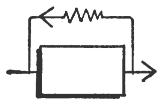
Pacemakers in the technology of our electronic age

Certain discoveries, inventions and developments of Bell Telephone Laboratories have been truly epochal in their effect upon the technology of our time. Each has come out of a single quest—a search for ways to make telephony ever better. But many have opened the way to exciting advances in TV, movies, radio, horology, astronomy. Here are ten of Bell Laboratories' contributions to the modern world.

Electronic amplifier. First high-vacuum electronic amplifier. Made possible long distance telephony and then opened the way to radio broadcasting.



Wave filter. Precisely separates bands of frequencies. Provided major key to economical sharing of the same wires by many voices or radio programs. Indispensable control tool in radio, television and radar.



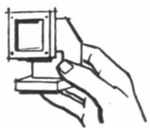
Negative feedback amplifier. Provides distortionless and stable amplification. Made possible the enormous, precisely controlled amplification needed in long distance telephone calls. The principle is now basic in high-quality amplifiers for radio, TV and high-fidelity reproduction.

Quartz crystal. Standard super-accurate quartz crystal oscillator developed for frequency controls in radio telephony. Has also become the standard control for clocks in world's astronomical laboratories.

Coaxial cable system. Hollow tube with a central conductor was developed to transmit hundreds of voices simultaneously. Now also provides long distance carrier for TV in partnership with microwave beams.

Transistor. Tiny solid-state device uses extremely small amounts of power to amplify signals. Makes possible electronic telephone switching and much smaller hearing aids, radios, TV sets and electronic computers.

Dial system "brain and memory." Takes over your call and sees that you are connected in the best and quickest way. Newest example: Direct Distance Dialing from home telephones to any part of the nation.



Waveguide. Hollow conductor transmits high-frequency waves. From this came the "pipe" circuits that are essential to radar and very short-wave radio communications.

Microwaves. Bell Laboratories developed long distance microwave transmission. It operates by focusing radio beams from station to station, carries cross-country telephony and TV.

Radio astronomy. This great new science began in the study of radio interference at Bell Laboratories . . . with the tremendous discovery that radio waves emanate from the stars.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT being the fastest, the new flyer adds also those of being the largest, the most commodious, and the steadiest ship afloat. That the *Lusitania* will be a 25-knot boat is now established by telegraphic dispatches from Liverpool, announcing that on the official trial, which lasted 48 hours, the ship maintained an average speed of 25¼ knots. Steaming at 25¼ knots, the *Lusitania* will bring the transatlantic record for the first time below five days—by just how much remains to be seen."

AUGUST, 1857: "The explorations of the northern coasts of America in search of a northern passage to the Pacific have been pretty effectually discontinued. If there is an open sea extending over the parts yet unreached, there may, at some future period, be inducements to explore it. At present the voyage round the almost equally dreary 'Horn,' sailing or steam-towing through the rocky Straits of Magellan, a canal along some line between the northern and southern continents, the Panama railroad, the Pacific railroad, the Pacific wagon road—some or all of these seem far more profitable and in every sense more desirable than attempts to crush a passage through ice floes in the Arctic Ocean. The search for Sir John Franklin's party—commenced this year by a small propeller vessel from England, the sides of which are very flaring, to induce the vessel to rise when pinched in the ice—is probably the last which will be undertaken. But it is nonetheless true that the explorations of the last 10 years have added to the wealth of the world by furnishing important scientific information. Within the last 40 years a coast line of more than 4,000 miles in those regions has been examined and accurately laid down upon navigators' charts. Terrestrial magnetism and the variation of the magnetic needle, astronomical observations and experiments with the pendulum for ascertaining the true form of the earth, ocean soundings and the freezing of salt water, records of the weather and the course of atmospheric circulation are subjects which have also received much attention."

"The project for a railway across the channel between France and England is strongly agitating the minds of many eminent engineers. One of the last and

F Y I

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▸ *New polyethylene pipe compound*
▸ *Ammonia data book*

Polyethylene pipe

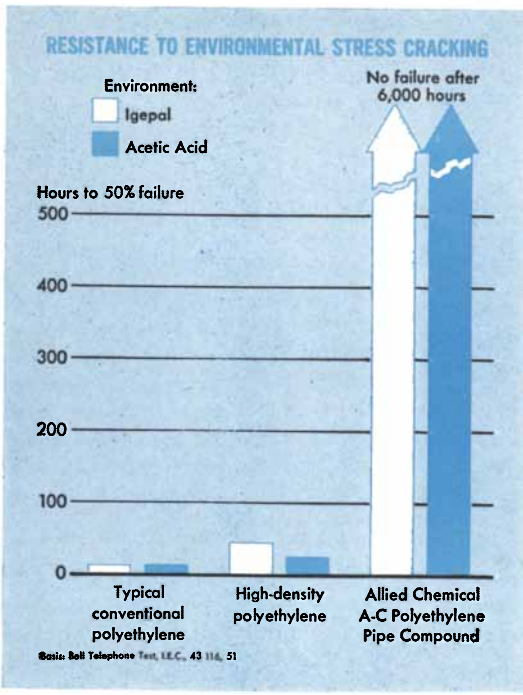
Flexible plastic pipe for water service and industrial applications. Chemical-resistant plastic pipe for transmission of solvents and hydrocarbons in the oil and gas fields. Pipe that is resistant to impact, heat and other stresses.

These are some of the advances made possible by a unique new polyethylene pipe compound developed by Allied Chemical. A very high molecular weight polyethylene, it is the successful culmination of 10 years of basic research at our Central Research Laboratories. It is now in commercial production.

Development work is now underway to find other uses for the resin's exceptional physical properties, for the time when the production rate permits sale beyond pipe manufacture. Likely candidates for new uses are tubings, films, sheets, tiles, moldings and fibers.

New plastic pipe made by Orangeburg Mfg. Co.

This distinctly different polyethylene resin made at low pressure is the best thing yet for extruding a superior polyethylene pipe. Pipe being made from the new A-C polyethylene pipe compound has high bursting strength, resistance to impact, shows no stress cracking, has superior heat resistance and resistance to chemicals, organic solvent and hydrocarbon liquids.



These properties are due to the high molecular weight—on the order of 750,000—and structure of the polyethylene molecule, not present in any other known polyethylene. These new qualities will greatly expand the acceptance of plastic pipe for water service and industrial applications. A common fault of some polyethylene pipe has been environmental stress cracking; this is entirely overcome in pipe made of this new resin.

Also, tests indicate the pipe will be suitable for carrying solvents and hydrocarbons for oil and gas pipe lines, a use denied to conventional polyethylene pipe. There is a growing need in this field for a flexible, tough pipe, resistant to the corrosive conditions which attack steel pipe.

A-C polyethylene pipe compound has an unusually high melt viscosity, reflecting its great molecular weight, and requires special techniques for manufacture of pipe.

The new resin is a companion product to a line of low molecular weight polyethylene products introduced on a commercial scale in 1954 by Allied. These are used in the injection molding of many household items, and as additives in paper coatings, polishes and printing inks.

A-C is an Allied Chemical trademark

Ammonia data book

A new 68-page technical book on ammonia has been prepared by the largest ammonia producer, Allied's Nitrogen Division.

The comprehensive manual is actually a two-in-one piece: the first section on ammonia, and the second on ammonia liquor. Its contents include major uses, physical and chemical properties, specifications, shipping and storage procedures, physical tables, graphs and analytical procedures.

Major ammonia consumers—industries such as explosives, textiles, petroleum refining, refrigeration, pulp and paper, metallurgy and synthetic resin—will be interested in this up-to-date information.

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☐ Polyethylene pipe
☐ Ammonia data book

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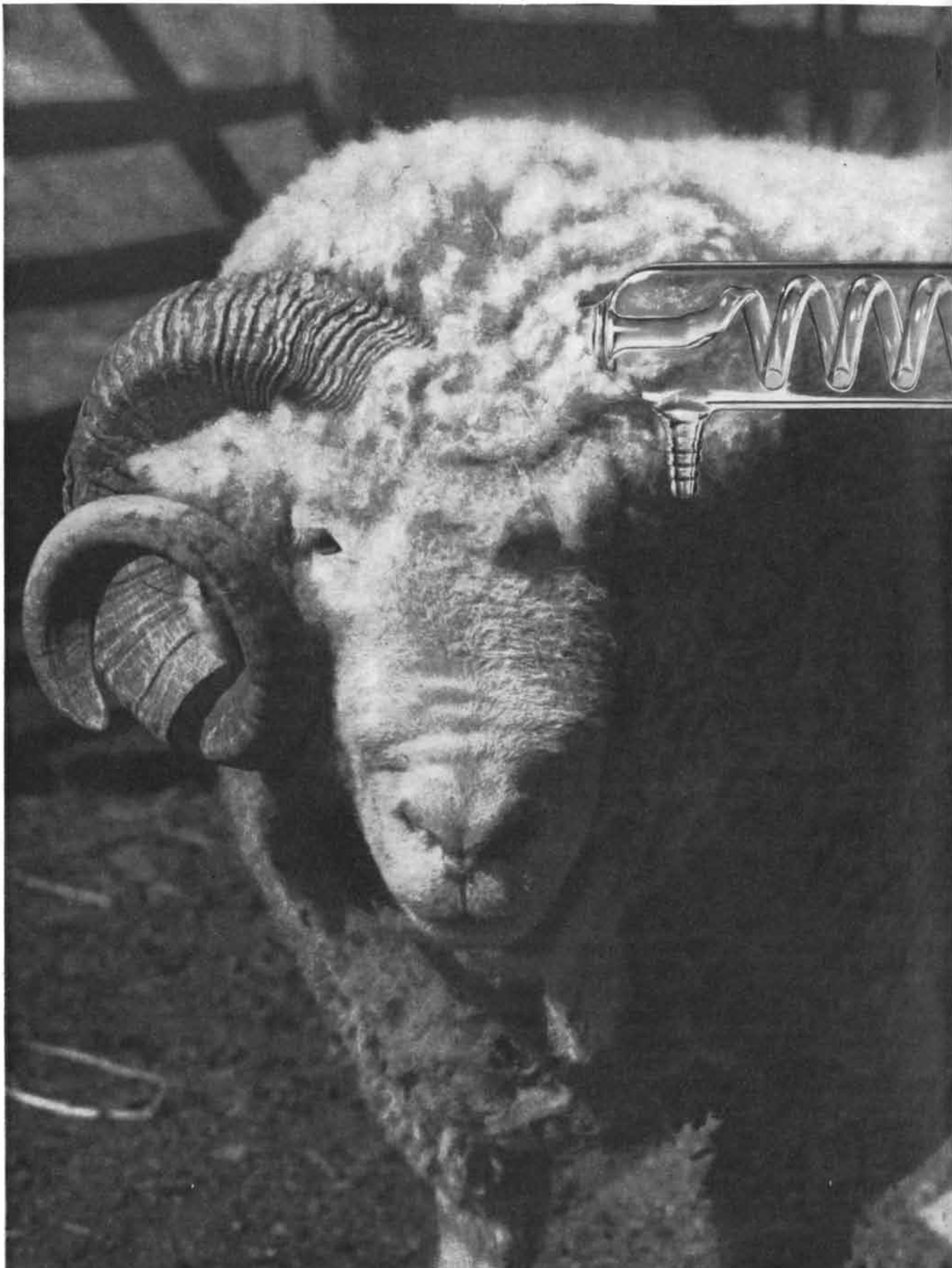
most practical is from a French architect, M. Horeau. He proposes an iron cylinder or tunnel, constructed similarly to the great Britannia Bridge. To a cylindrical tube he gives the preference, the same to be large enough for two tracks to be laid on the bed of the sea, and to be supported and fastened at intervals of about one mile by pyramids also of iron, to reach above the surface of the sea, to be lighted by night, and to be at all times a beacon for sailing vessels. These beacons are intended also to prevent anchorage in the neighborhood of the tube, the length of which will be nearly 21 miles."

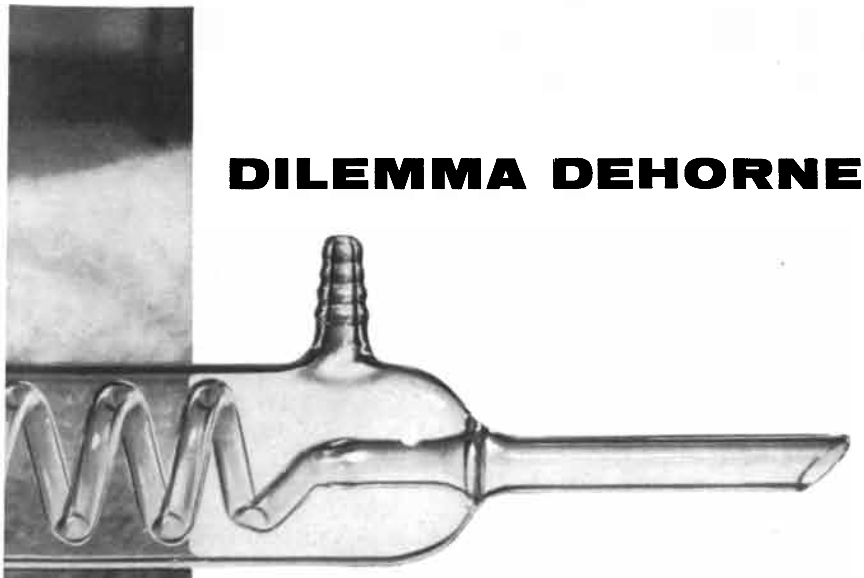
"According to the observations made by M. Rudolphe Wolf, Director of the Observatory at Berne, it appears that the number of spots on the sun have their maximum and minimum at the same time as the variations in the needle of the compass. It follows from this that the cause of these two changes on the sun and on the earth must be the same, and consequently, from this discovery, it will be possible to solve several important problems in connection with these well-known phenomena, the solution of which has hitherto never been attempted."

"While the pen is inscribing these lines, the cable by which it is hoped to connect the wealth of the Old World with the enterprise and vigor of the New is probably being rapidly reeled off and allowed to sink on the dark bottom of the Atlantic. It is probable that before the slow progress of the mails can deliver these sheets to a majority of our readers, the general results of the effort will be known and circulated on the wings of lightning to the furthest limits now reached by this great agent of intelligence. If the enterprise proves successful, and if signals are made with the force, certainty and speed requisite for the transmission of dispatches, the event should be celebrated by rejoicings, compared with which the *fêtes* in memory of the old Roman victories should sink into absolute insignificance. It is a victory over immense natural difficulties, a leaping over space, an annihilation of time, a defiant trespass on the terrific depths of the ocean; a real *practical* triumph, and one which should, as it undoubtedly will, mark an era in the progress of the world."

"Professor Joseph Henry, the distinguished head of the Smithsonian Institution, testifies that he knows but one man among the scientific men of the U. S. who is an infidel."



DILEMMA DEHORNED



For centuries huge woven felts of pure wool have carried paper from the screens to the drying rolls on every paper machine in the world. Wool gives these felts the finish and drainage vital in making quality papers at low cost. But as paper-machine speeds increased, woolen felts began to wear out sooner. Some machines had to shut down every few days to change felts—and such shutdowns were very costly.

Then along came synthetic fibers with greater strength and resistance to abrasion, providing a partial answer. But unfortunately, felts containing too much synthetic fiber do not impart the finish essential to many types of paper. As you blend synthetics with wool to gain toughness on the one hand, you may sacrifice finish on the other.

Dilemma.

Huyck (pronounced Hike) characteristically approached the dilemma from a new direction. After years of research, F. C. Huyck & Sons perfected a chemical process that makes the natural wool fiber wear like a synthetic, while retaining wool's soft, cushiony, resilient characteristics. This revolutionary 4-D treatment of Huyck Papermakers' Felts is proving a tremendous boon to the paper industry.

Through this type of research F. C. Huyck & Sons is keeping pace with the technological advances in papermaking, a reason Huyck has grown as an integral part of the prospering and stable paper industry since 1870.

HUYCK PAPERMAKERS' FELT DIVISION OF

F. C. HUYCK & SONS

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WALDORF Instrument Division, Plants at
Huntington Station and Dix Hills, L. I., New York

THE AUTHORS

JOANNE STARR MALKUS ("The Origin of Hurricanes") took her first course in meteorology as an undergraduate at the University of Chicago in order to qualify as a civilian pilot. The subject so fascinated her that she entered the University's Institute of Meteorology and, after a World War II leave of absence to instruct student weather officers, she received her Ph.D. there in 1949. Mrs. Malkus taught at the Illinois Institute of Technology for several years. Since 1951 she has been a meteorologist at the Woods Hole Oceanographic Institution, where she directs two research projects on tropical weather, one sponsored by the Office of Naval Research and the other by the U. S. Weather Bureau. In the course of this work she has made a number of flights through tropical disturbances in the Woods Hole PBY seaplane. In 1954 and 1955, Mrs. Malkus was a Guggenheim Fellow and taught meteorology at Imperial College of Science and Technology in London. She is married to Willem van Rensselaer Malkus, a physicist at Woods Hole, and has two sons. Her article entitled "Trade-Wind Clouds" appeared in the November, 1953, SCIENTIFIC AMERICAN.

HENRY F. IVEY ("Electroluminescence") is in charge of the phosphor section of the Westinghouse Electric Corporation. He was trained in physics at the University of Georgia and the Massachusetts Institute of Technology, where he earned his Ph. D. in 1944. As a staff member of the M.I.T. Radiation Laboratory during World War II, Ivey worked on cathode-ray screens for radar. This led him to research on the luminescence of television screens and on the new lighting technique which he describes in his article.

SIR JAMES GRAY ("How Fishes Swim") has been head of the department of zoology of the University of Cambridge for 20 years. In addition to his academic duties, he is the British Government's Development Commissioner for Fishery Research and a trustee of the British Museum. Born in 1891, he was elected a fellow of King's College, Cambridge, in 1914. During World War I he was a captain in the Queen's Royal West Surrey Regiment and won the Military Cross and Croix de Guerre with Palm. A long-time student of animal movement, Sir James

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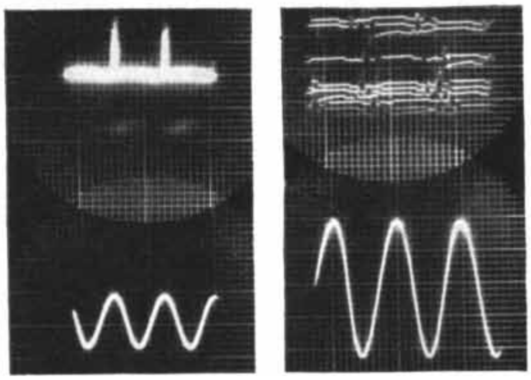
L to R: Dr. Fricke, Engineer-in-charge Acoustics Laboratory, and Mr. Kuzara, Acoustics Engineer, evaluating a component in a high intensity acoustic environment. RIGHT: Malfunction of a relay at high-intensity sound as disclosed in a sound chamber.



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writes that he first studied fish as a result of trying to explain the movement of single cells. The lash of a spermatozoon's tail led him to observe eels, and eels led him to fishes and dolphins. He is the author of the well-known book *How Animals Move.*

GEORG VON BEKESY ("The Ear") is a senior research fellow in psychophysics at Harvard University. Born in Hungary in 1899, he studied at the universities of Berne and Budapest and received a Ph.D. from the latter in 1923. Besides the teaching posts which he held at the University of Budapest, von Békésy was for many years a research scientist with the Hungarian telephone system. His work on adapting telephone receivers to the mechanics of the ear led eventually to a revision of the theory of hearing. After leaving Hungary in 1947 he was for several years a research professor at the Karolinska Institute in Stockholm as well as a fellow at Harvard. In 1955 he received the Howard Crosby Warren Medal of the Society of Experimental Psychologists.

GABRIEL M. GIANNINI ("The Plasma Jet") is a California industrialist whose father and grandfather were respectively professors of admiralty law and Italian literature. Born in Rome in 1905, he graduated from the Institute of Physics of the University of Rome, where he studied with Enrico Fermi. He came to the U. S. in 1930. After 10 years of work on the engineering of loudspeaker systems, he became interested in aviation and developed the aircraft instruments which are now manufactured by G. M. Giannini Co., Inc. In addition, he directs the Giannini Research Laboratory for research on plasmas. In 1953 Giannini, after withdrawing a $10 million court action, induced the U. S. Government to settle for $300,000 the claim of Fermi and his associates that their patents on the "moderation" of neutrons—applied for on their behalf by Giannini—had been infringed by the Atomic Energy Commission.

THEODORE T. PUCK ("Single Human Cells in Vitro") studied biophysics under the Nobel laureate James Franck at the University of Chicago and received his Ph.D. there in 1940, at the age of 23. After several years of research in the University of Chicago Department of Medicine, he went in 1947 to the California Institute of Technology as a senior fellow of the American Cancer Society in order to study bacteriophage with Max Delbrück. The following year

Photo courtesy Union Tank Car Company, Chicago, Illinois. Insulation hardboard supplied by Rubatex Division, Great American Industries, Inc., Bedford, Virginia

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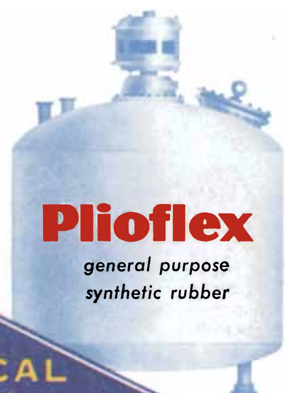
It's a cold fact: Proper insulation is the key to low-cost storage and transportation at low temperatures. Being applied above to liquid carbon dioxide cars is a lightweight hardboard made of expanded PLIOFLEX rubber which does a matchless job of efficiently and economically shutting cold, heat and moisture—in or out.

Millions of tiny, closed cells—filled with nitrogen and bound by tough hard rubber—give this board the lowest conductivity of any known structural material. It also is strong enough to be used in self-supporting construction, does not require a vapor barrier and can be easily cut to shape and installed.

When first introduced, this product was made from natural rubber. But wartime shortages caused a change to synthetic rubber which, because of its uniformity, soon proved to be much more satisfactory. PLIOFLEX is used today because of its unusually high uniformity and consistently low moisture content.

Just one of many uses for versatile PLIOFLEX is chemically blown insulation. How can you use this high-quality, "hot," "cold" or oil-extended rubber to advantage? Find out by writing for details to: Goodyear, Chemical Division, Dept. H-9457, Akron 16, Ohio.



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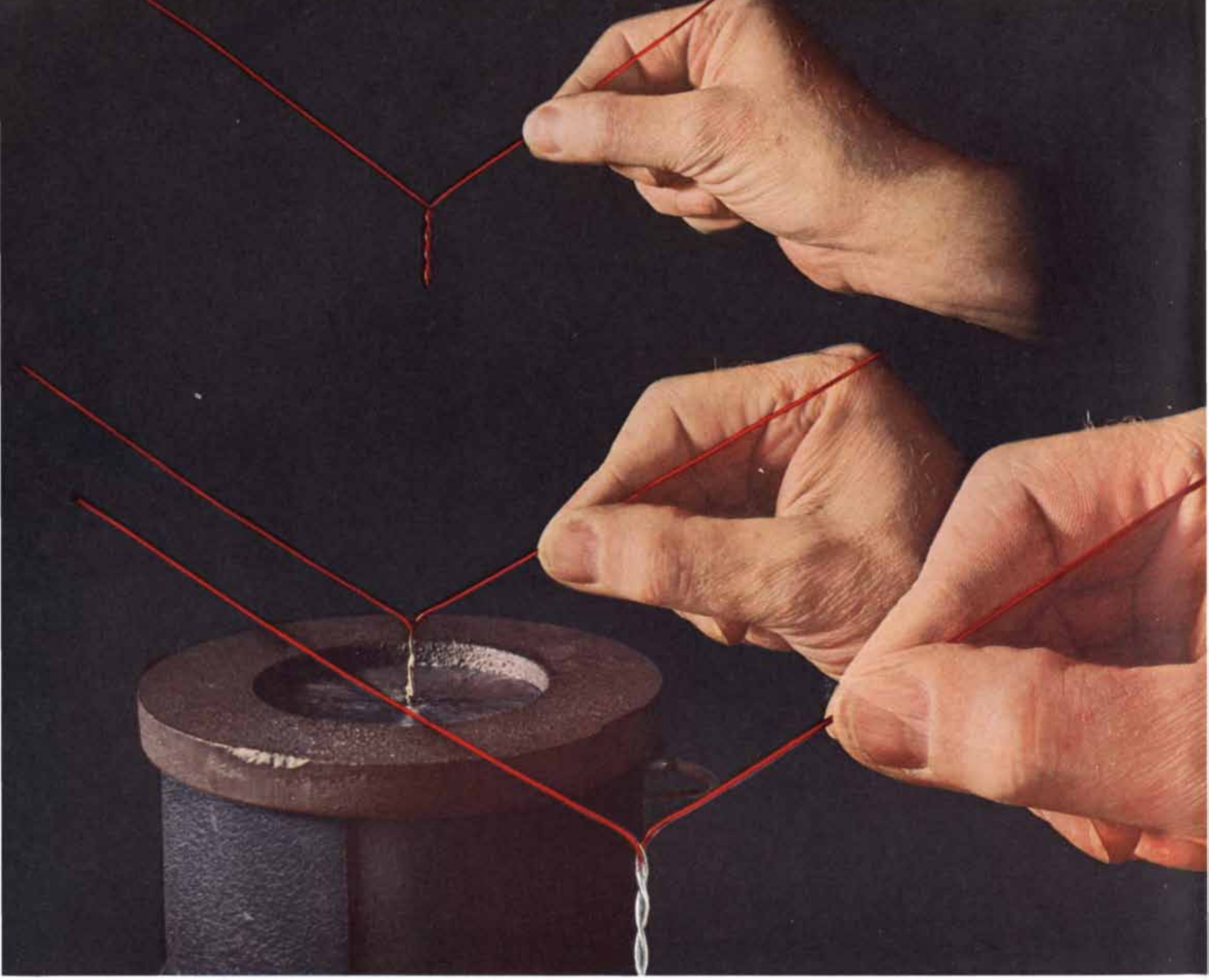
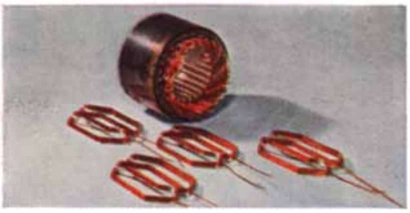


Twist wires . . . dip in solder . . . joint is complete without first removing the insulation—with Anaconda's new Analac magnet wire.

Soldering without stripping the insulation speeds production



Motor stator and coils wound with Anaconda's solderable magnet wire.

THE PROBLEM: Remember the struggles you've had in removing the insulation from electric wires before joining the conductors? Manufacturers of coils and transformers for electric devices have a similar problem—and it's costly.

They may produce many thousands of coils every day. Stripping off the thin insulation on the magnet wire that goes into these windings eats up time and money. In very fine wire, the problem is even worse: the conductor can be easily damaged.

THE SOLUTION: For years, wire and cable manufacturers worked to develop a magnet wire that could be soldered without first stripping the insulation. But insulated wires that were "solderable" lost vital properties. Finally, Anaconda engineers came up with a long-sought insulation: "Analac." Now electronic manufacturers and other users have a reliable, solderable magnet wire. Result: faster production . . . lower costs.

THE FUTURE: At Anaconda Wire and Cable Company, the kind of skill that solved this knotty problem helps provide the wires and cables for the expanding needs of *all* industry. Anaconda's other fabricating company — The American Brass Company—also serves industry with a complete line of copper and copper alloys in the form of sheet, strip, wire, rod, tube and special shapes. Whatever your problem, whatever your industry — the Man from Anaconda is ready to help you. Call him today. The Anaconda Company, 25 Broadway, New York 4, N. Y. 57258

ANACONDA®

ANACONDA WIRE & CABLE COMPANY—THE AMERICAN BRASS COMPANY

Puck, then 31, was appointed professor by the University of Colorado in order to found a department of biophysics.

MARVIN K. OPLER ("Schizophrenia and Culture") works on the borderline between anthropology and social psychiatry—both of which subjects he teaches at Cornell University Medical College in New York. (He is not to be confused with his brother, Morris Opler, professor of anthropology at the Ithaca, N.Y., campus of Cornell.) A student of Franz Boas at Columbia University, where he took his Ph.D. in 1938, Opler studied the Eskimos and coastal Indians of North America with Vilhjalmur Stefansson and later observed mentally ill members of some of these same groups at a hospital for Alaskans in Portland, Ore. From 1938 to 1943 Opler was professor of anthropology at Reed College. He then served as community analyst in the wartime segregation center for Japanese-Americans at Tule Lake, Calif. Since World War II he has taught at Stanford and Harvard as well as at the Cornell Medical College.

JEAN CADART ("The Edible Snail") is director of the Ecole Cité Jardins in Champigny, France. His association with the edible snail began in 1923, when he found his schoolteacher's salary inadequate to support himself, his wife and their aged parents. One day, while meditating his problems in the woods, he saw a snail. "With a shock," he writes, "I realized that this mollusk would be my savior." In his spare time Cadart began to raise snails, with sufficient success for him to be able to send his two daughters to college. (One is now a physician; the other, an electronics engineer.) On his days off Cadart mingled with snail merchants, who were amused by the snail-raising schoolteacher and plied him with questions about snails. In order to answer the questions Cadart began to perform experiments. Later, in response to a suggestion by Gilbert Ranson of the Museum of Natural History in Paris, he undertook to write a book summarizing everything he knew about snails. This work, entitled *Les Escargots,* appeared in 1955.

JANE OPPENHEIMER, who reviews *Life: An Introduction to Biology* in this issue, is professor of biology at Bryn Mawr College. A Bryn Mawr graduate, she received a Ph.D. in zoology from Yale University in 1935, and later held a Sterling fellowship in biology at Yale. Among her other academic awards have been two Guggenheim fellowships.

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Polaroid Corporation Announces

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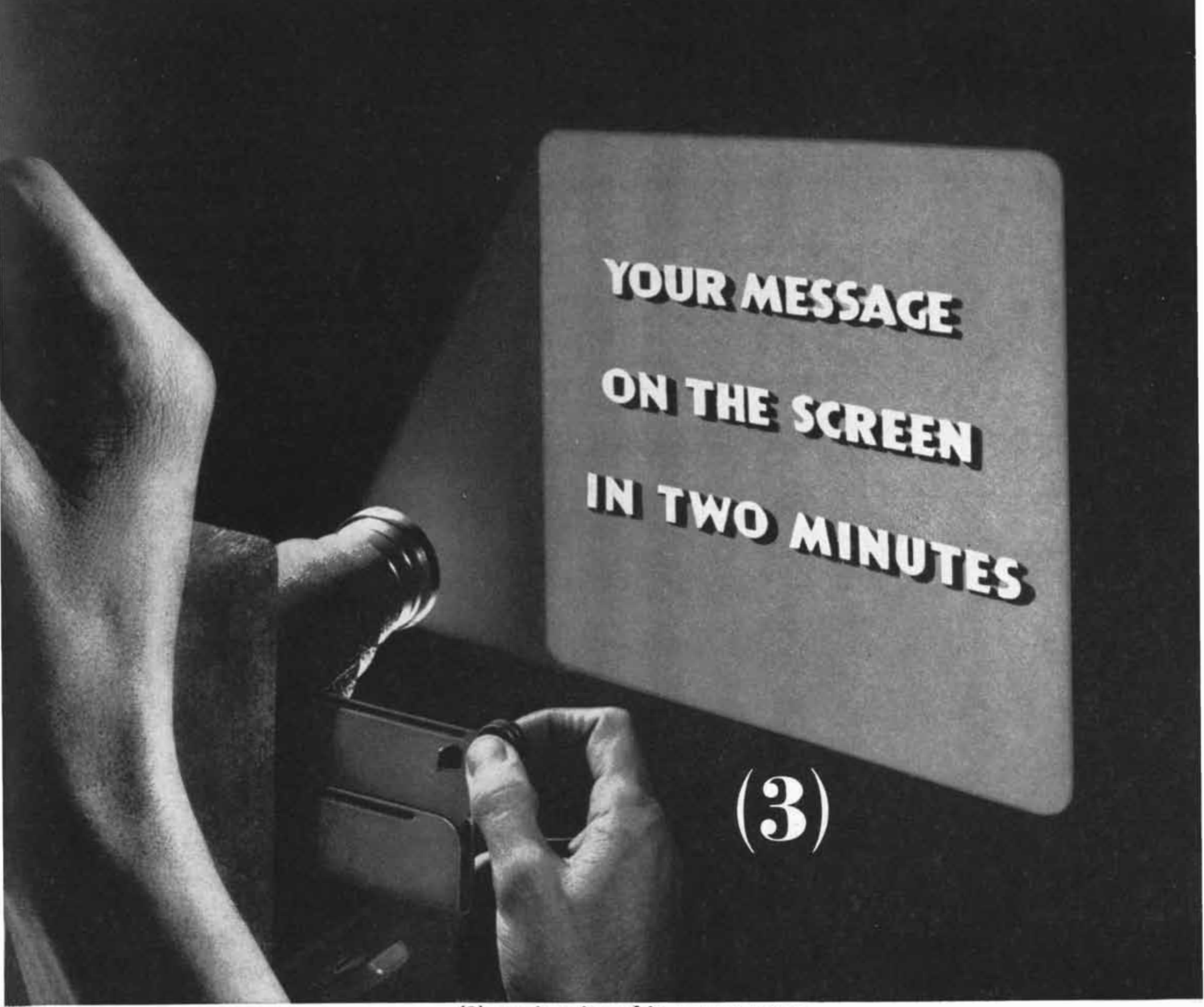
Polaroid Corporation has perfected a film which produces black-and-white slides right in the camera. You simply load a *regular* Land camera with this new film, click the shutter, pull a tab and lift out a transparency of exceptional photographic quality. It's ready to project 20 seconds later, after a quick hardening and mounting in a snap-together plastic mount. It's now as easy to use slides in your work as it is to pick up a phone or dictate a letter.

The complete system includes the standard Polaroid® Land Camera, the film, mounts, hardener and projector, plus a versatile Copymaker that lets you make slides from any text material, existing photographs, charts, graphs, titles or what have you. You have a choice of two sizes of film—2¼ x 2¼, or 3¼ x 4 (for existing "Lantern Slide" projectors). The quality of the film is remarkable—brilliant, grainless, and so sharp that projection to 12-foot



(2) Simply slip it into a mount, and (3) project it as big as you want.

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screens shows no loss of detail. And it's extraordinarily fast (speaking photographically, now)—daylight speed of 1000 (ASA equivalent exposure index).

The slides cost about one-third as much as conventional slides. But the real saving is in the time and effort that it takes to put a picture on the screen. Whenever you've been on your feet before a group, you've felt the need for a key picture (or perhaps several) to make sure your information gets across. Now you can make those pictures right in your office, classroom or laboratory and begin to use your listeners' eyes as well as their ears. Send in this coupon for more detailed information.

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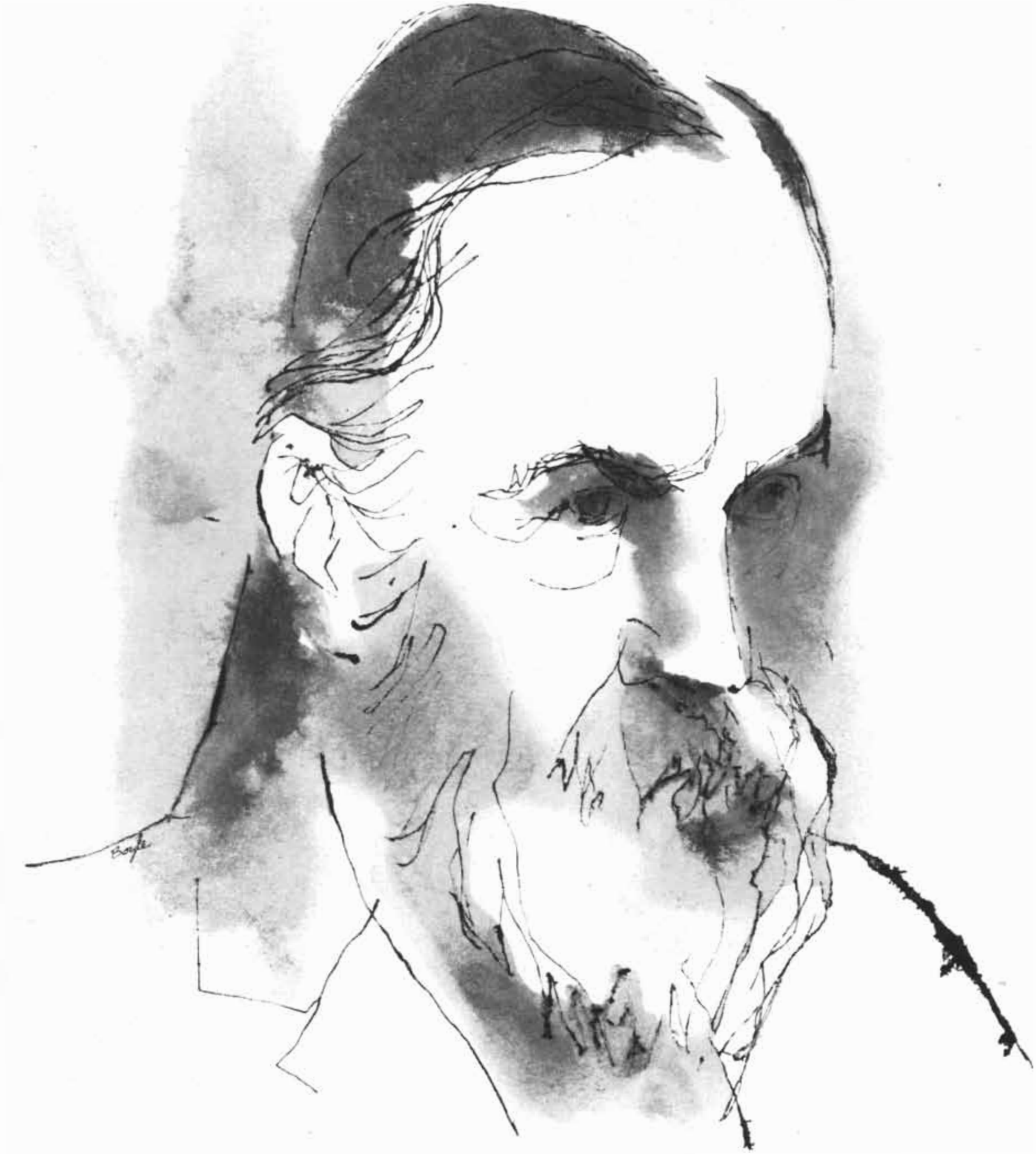


Established 1845 SCIENTIFIC AMERICAN August, 1957 Volume 197 Number 2

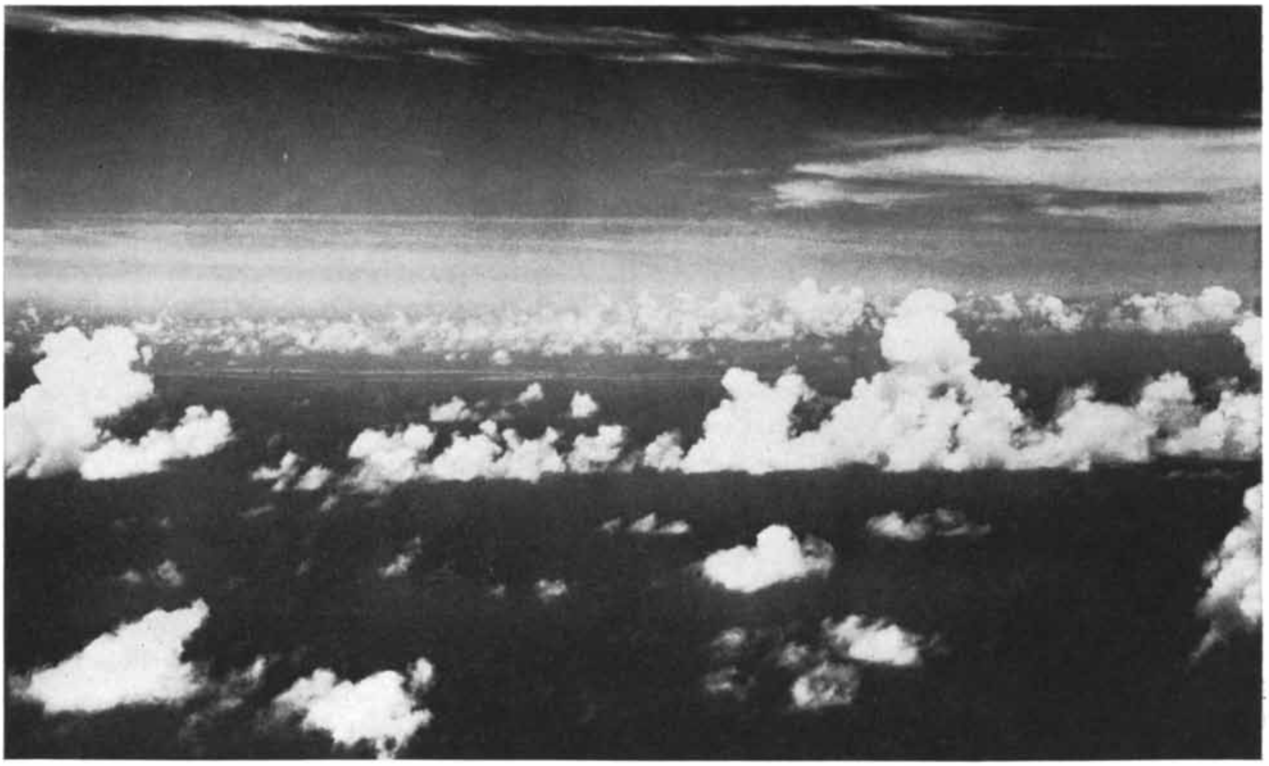
The Origin of Hurricanes

During the summer the uniform weather of the tropics is periodically disturbed. Occasionally these disturbances ripen into hurricanes. Why they do not do so more often is still a basic question of meteorology

by Joanne Starr Malkus

The weather of the tropics is notoriously monotonous. The wind always blows from the same direction, and airports need only a single runway. A daily shower, so we are told, arrives with clocklike regularity. The temperature is so even all the year round that a five-degree drop makes people shiver. A tedious climatic uniformity sits upon land and ocean alike. How is it, then, that these impassive tropics generate one of the most violent weather phenomena known to man? The fact that hurricanes are hatched in the seemingly peaceful tropical regions is one of the great paradoxes of meteorology.

Like all paradoxes, this one has a surprising answer. The atmosphere of the tropics is not as placid as it seems: its apparent tranquillity lies only on the surface. Probing into the higher levels,

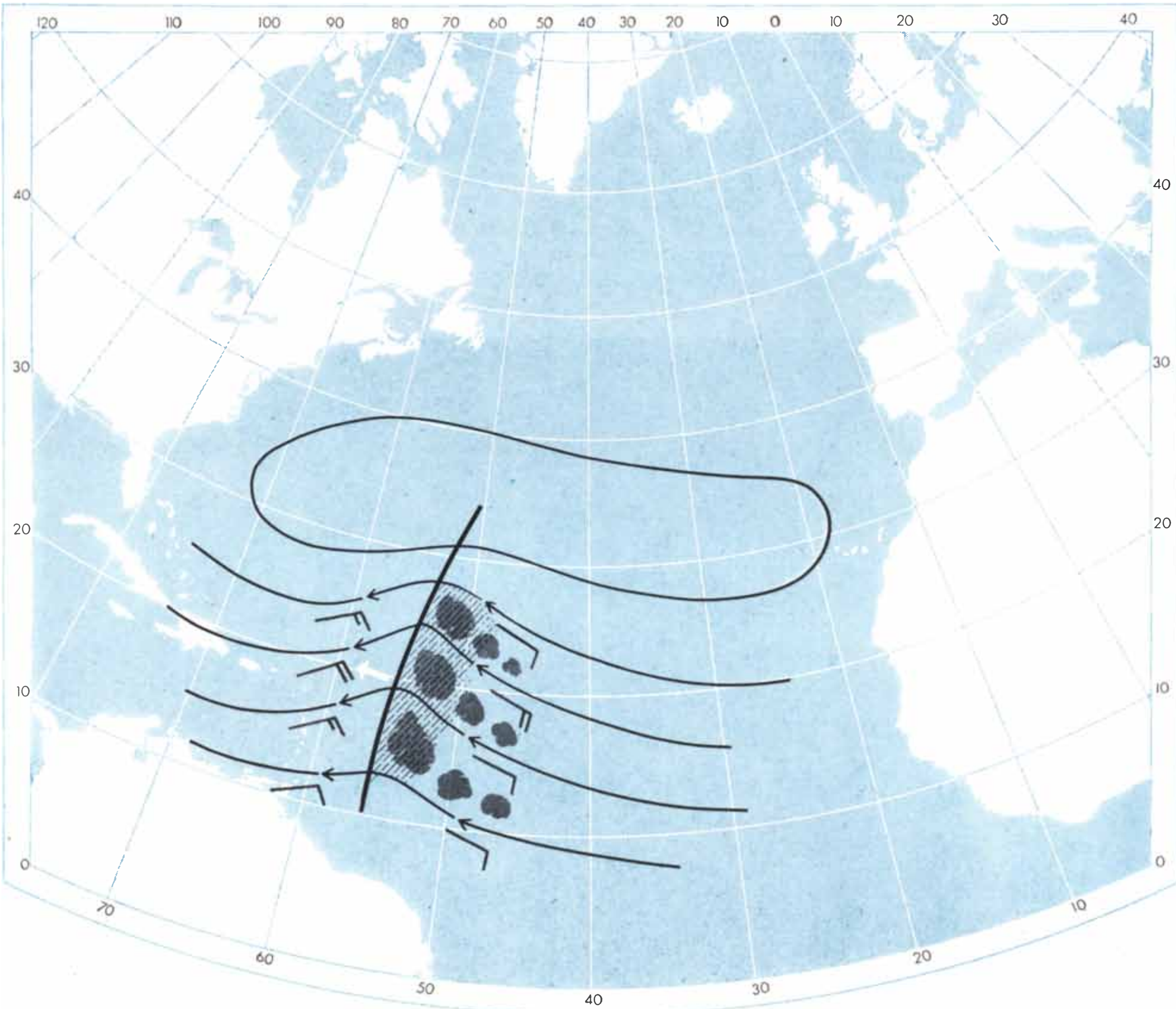


CUMULUS CLOUDS are a characteristic feature of an ordinary day in the Caribbean. In this photograph, made from a PBY aircraft of the Woods Hole Oceanographic Institution, the trade wind blows from left to right. The tallest clouds rise about 6,000 feet.

meteorologists have discovered that the air aloft is far more disturbed than one might guess at ground level. In fact, the situation in the tropical regions is just the reverse of the familiar picture in our so-called temperate zones. Our wind flow is variable near the ground and comparatively steady at high altitudes; in the tropics it is steady below and variable aloft. Storms are almost as frequent in the tropics as in our proverbially fickle climate, but they have a different character and develop in a different way.

Our middle latitudes are a battleground of cold and warm air masses. Clashes between these masses form great rotating cells of air, which bring dramatic changes of air flow and temperature at the ground when they pass over a given area. Thus in our latitudes the winds may shift suddenly and may blow from any direction. We broil or freeze or enjoy days of balmy weather—depending upon what corner of the moving battlefield we find ourselves in at a given time. At the front between contrasting air masses there may be a temperature difference of 50 degrees or more within 100 miles. It is the energy supplied by these clashes between masses of sharply different temperatures—"potential" energy released by the sinking of the cold air and the rise of the warm—that powers our storms.

In the tropics conditions are entirely different. The lower air, up to about 8,000 feet, is a single, homogeneous mass covering thousands of miles of warm ocean. The wind blows steadily and uniformly from east to west. The energy that generates storms comes not from clashes of air masses but from the evaporation of water from the warm seas, storing latent heat in vapor form [see "Trade-Wind Clouds," by Joanne Starr Malkus, SCIENTIFIC AMERICAN, November, 1953; and "Hurricanes," by R. H. Simpson, June, 1954]. The vapor is pumped high into the atmosphere in cumulus clouds. When the clouds rise to great heights—10,000 to 20,000 feet or more—the vapor may condense into heavy rains and thus re-



EASTERLY WAVE is a deflection of the trade winds. The map at left shows the deflection at the surface. The heavy black line indicates the trough of the wave; the long arrows and barbed symbols, the deflected winds. Each short barb (the long barbs consist of two

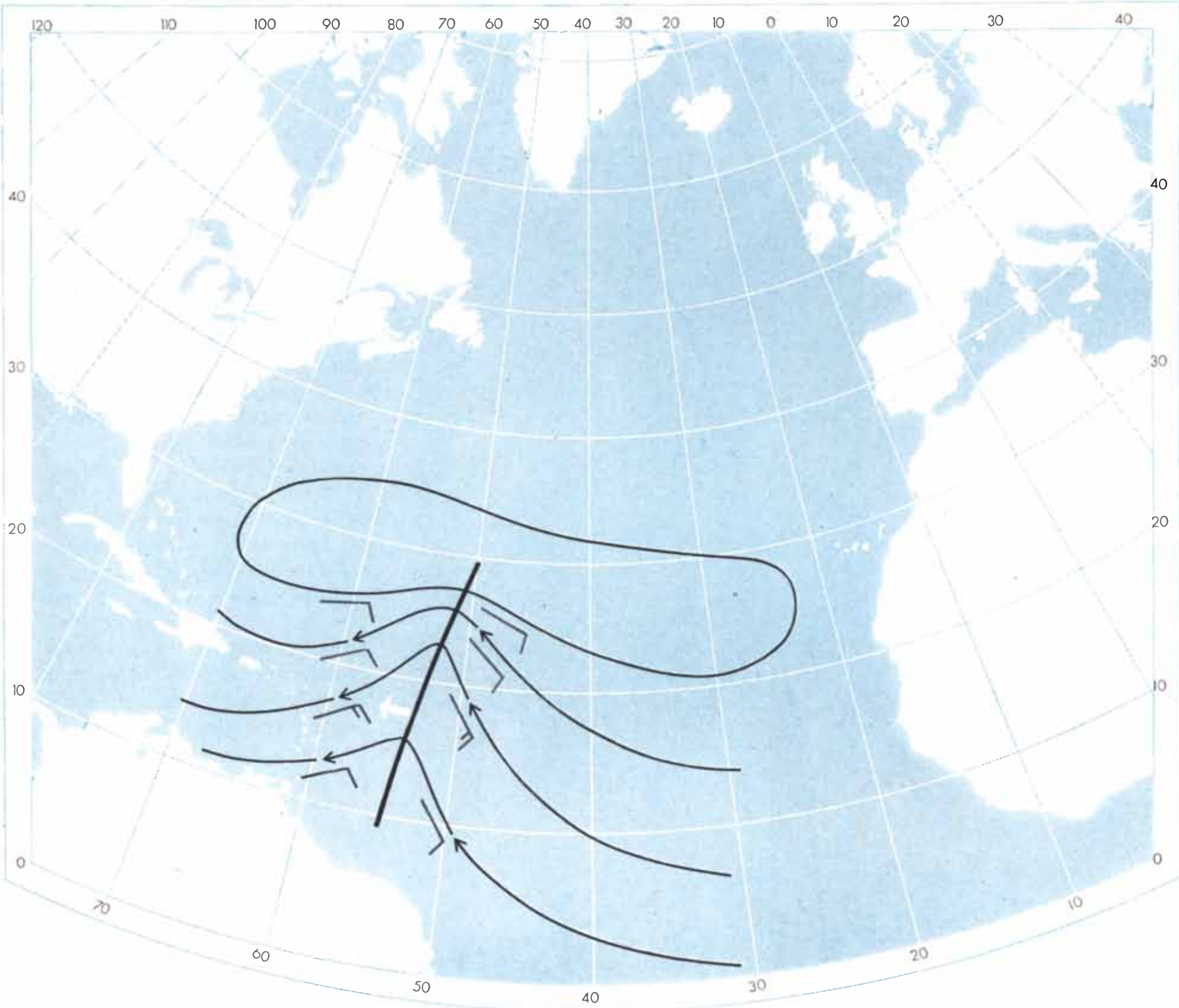
lease large amounts of the latent energy.

The upper air in tropical regions is extremely restless. Winds may blow from any direction, and often great wavelike disturbances, as much as 1,000 miles across, sweep through the trade-wind current. It is from these disturbances that hurricanes develop. However, while the wavelike disturbances occur frequently, hurricanes are comparatively rare. Thus the real puzzle for meteorologists is not why the tropical regions produce hurricanes but why they produce so *few* hurricanes!

The vast frontier of the tropical atmosphere has been explored intensively since World War II, by means of ships, aircraft, radiosonde and radiowind stations and all the apparatus of modern meteorology. The U. S. Weather Bureau, the Woods Hole Oceanographic Institution, the University of Chicago and other groups have collaborated in a big project to learn the cause and development of hurricanes. There are no final answers yet, but many of the pieces of the puzzle are beginning to fit together.

One of the first clues, discovered by careful study of weather records, is that the notion about regular rainfall in the tropics is a myth. Significant rains are not daily occurrences and are apt to be concentrated within one or two periods in a month. This suggests that the rains stem from systematic disturbances of the upper atmosphere. As I have mentioned, severe storms are fairly frequent in the tropics. During the summer one or more major disturbances is constantly brewing in the Caribbean. Yet at most only one in 10 of these grows up to be a hurricane. Why so? What is the particular set of conditions necessary to hatch a full-fledged Betsy or Diane? We can best attack the problem by considering step by step just how a tropical disturbance develops.

One of the most important types of summertime disturbances of the wind pattern in the tropics is the wavelike deflection of the trade winds, advancing on a broad front. It is a kind of dent in the trade current, producing shifts in

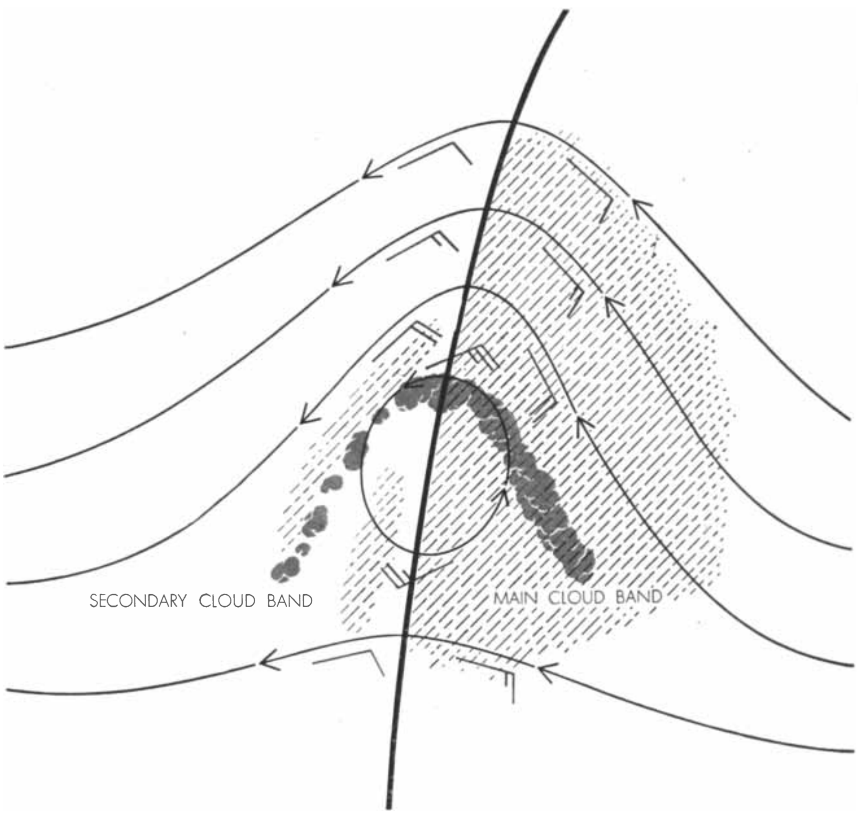


short ones) represents a wind velocity of five miles per hour. Behind the trough it is cloudy and rainy. The closed loop at the upper end of the trough is a high-pressure area. The map at right shows winds of the same disturbance at an altitude of 15,000 feet.

the wind direction: ahead of the wave the trade wind blows slightly north of east; behind it, slightly south of east [*see diagram on page 34*]. In advance of this eastward disturbance (known as the "easterly wave") the weather is unusually clear, but in its train come thick clouds and rain. The reason is that the wave wipes out the boundary (called the "trade-wind inversion") which normally divides the moist lower air from the dry upper air at a level of around 6,000 to 10,000 feet in the tropical atmosphere. Moist air therefore funnels up as high as 50,000 feet. In this moist air cumulus clouds can grow to towering heights and become raining thunderheads [*see lower diagram on opposite page*].

This suffices to account for a rainstorm, but the main ingredients of a hurricane are still missing. We need a vortex for the storm. And we find it making its entry at the next stage of intensity in tropical storms. Above about 30,000 feet the steady trade winds peter out and, as we have noted, the tropical atmosphere becomes turbulent and variable. Here we find cyclones and anticyclones—great eddies of air like those of temperate latitudes, except that in the tropics they float above instead of below the prevailing winds of the region. If an anticyclone happens to drift across an easterly wave, it begins at once to intensify the disturbance. The anticyclone pumps air outward from the eddy at high levels, and air is therefore pulled into the storm at its bottom. The pressure at the center of the cyclone drops. As a result of the inflow of air and the earth's rotation, the spin of the cyclone speeds up and it becomes a closed vortex with winds of 35 to 45 miles per hour. A large cloud band develops, extending southeast from the vortex, and often many secondary cloud bands [*see diagram below*]. Squalls and thunderheads multiply; the rain intensifies; showers break out ahead of the advancing disturbance.

The storm now has many of the features of a hurricane. Will it inevitably grow into one from this stage? The answer is no. More than half of these storms, even with the developed vortex, come to an ignominious end within a few days. Something more is necessary to make a hurricane.



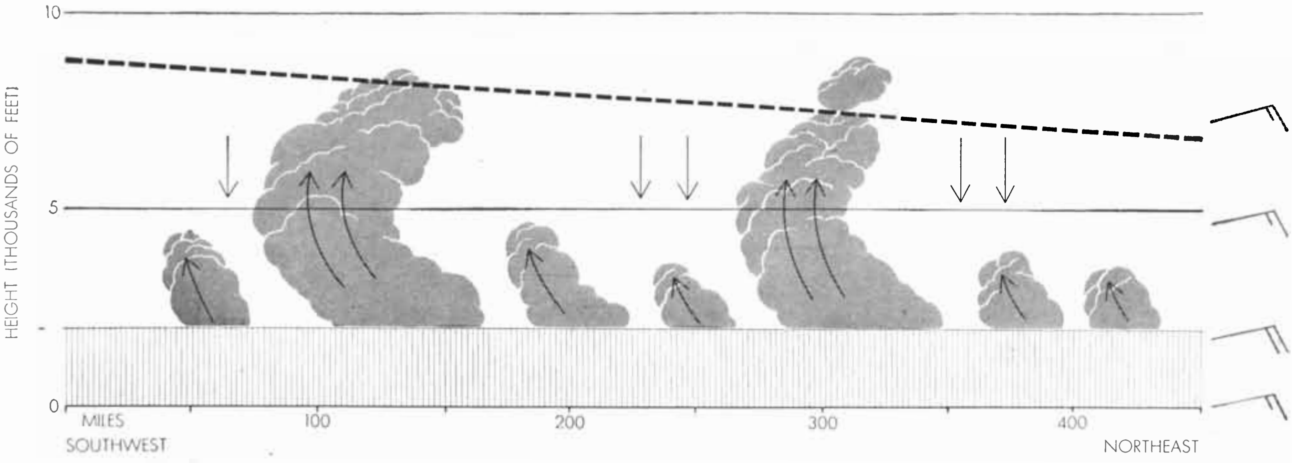
VERY DEEP EASTERLY WAVE, mapped in the same way as the wave on the preceding two pages, develops a central vortex (*closed loop*). The hatched area is cloudy and rainy.

Let us look at a hurricane itself to see if we can find any distinguishing features. We find one clear clue in the temperature of the core. In a storm of the kind just described, the core is a little colder than the surroundings; in a hurricane, on the other hand, it is warmer. The more vicious the storm, the warmer its center; some Pacific typhoons are 10 to 15 degrees F. warmer than the environs at high levels. A warm core seems to be crucial to development of a hurricane for two reasons: (1) because the inflow into this center of less dense air at the bottom permits the vortex to wind up to high speed, and (2) because at high levels the warm air of the center has a higher pressure than the surroundings and therefore flows out of the core, allowing the circulation of the vortex to continue unimpeded.

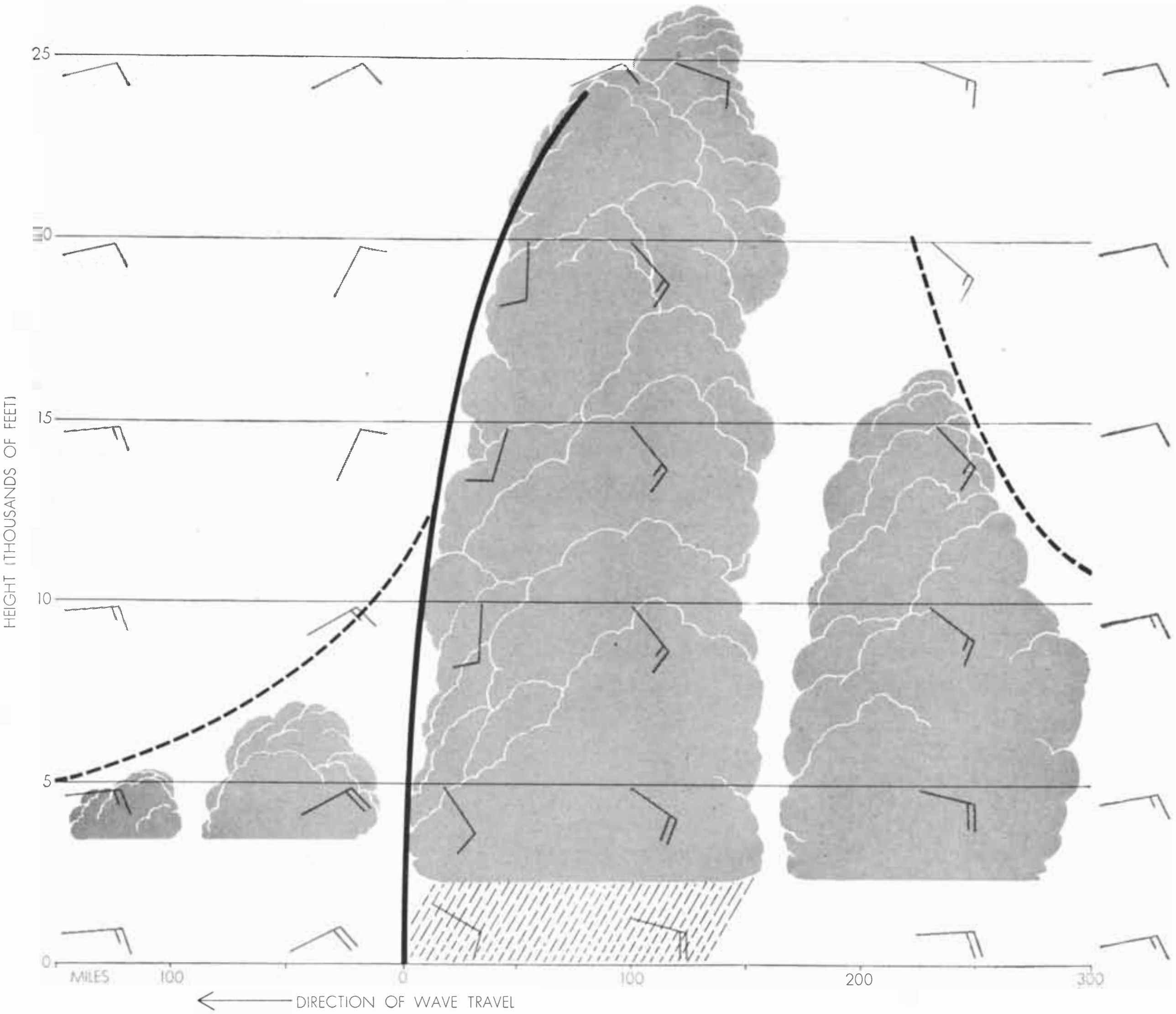
What produces a warm core? We know that the basic source of energy for tropical storms is the latent heat of water vapor, released when the vapor condenses. It seems logical to assume that this process—moist air rising from the sea and condensing into cumulus clouds—is responsible for the warming of a storm core. But the process will not go very far if the moist air is diluted with drier, cooler air as it rises. The clouds rise to great heights only when the warm, wet air is funneled upward without much mixing with dry air. A disturbance such as an easterly wave, as we have seen, raises the roof of moisture and permits the clouds to build up to towering heights. In most cases, some cool, dry air is drawn into the rising air column from the surroundings. It is only when all or nearly all of the air ascending to the cloud tops has risen from the moist base that we get a warm core.

Is the storm now ripe? Do we invariably get a hurricane under these conditions? Again the answer is, not necessarily. We have arrived at a condition which is probably necessary but not sufficient. The core is not yet warm enough: it may be five or six degrees warmer than the surroundings, but in a hurricane it is 10 to 15 degrees warmer. An additional warming mechanism seems to be required. This is probably where the famous "eye" comes in.

The eye of a hurricane is its most remarkable feature. Within the wall of towering thunderheads and raging squalls is an oasis of calm 10 to 30 miles across—often sunny and completely free of clouds. This eye plays a vital role in the formation and maintenance of a hur-



NORMAL CUMULUS CLOUDS of the tropics are shown in cross section. The broken line at the top of the clouds marks the trade-wind inversion, which divides the moist lower air from the dry upper air. Scale of clouds on this page is greatly exaggerated.



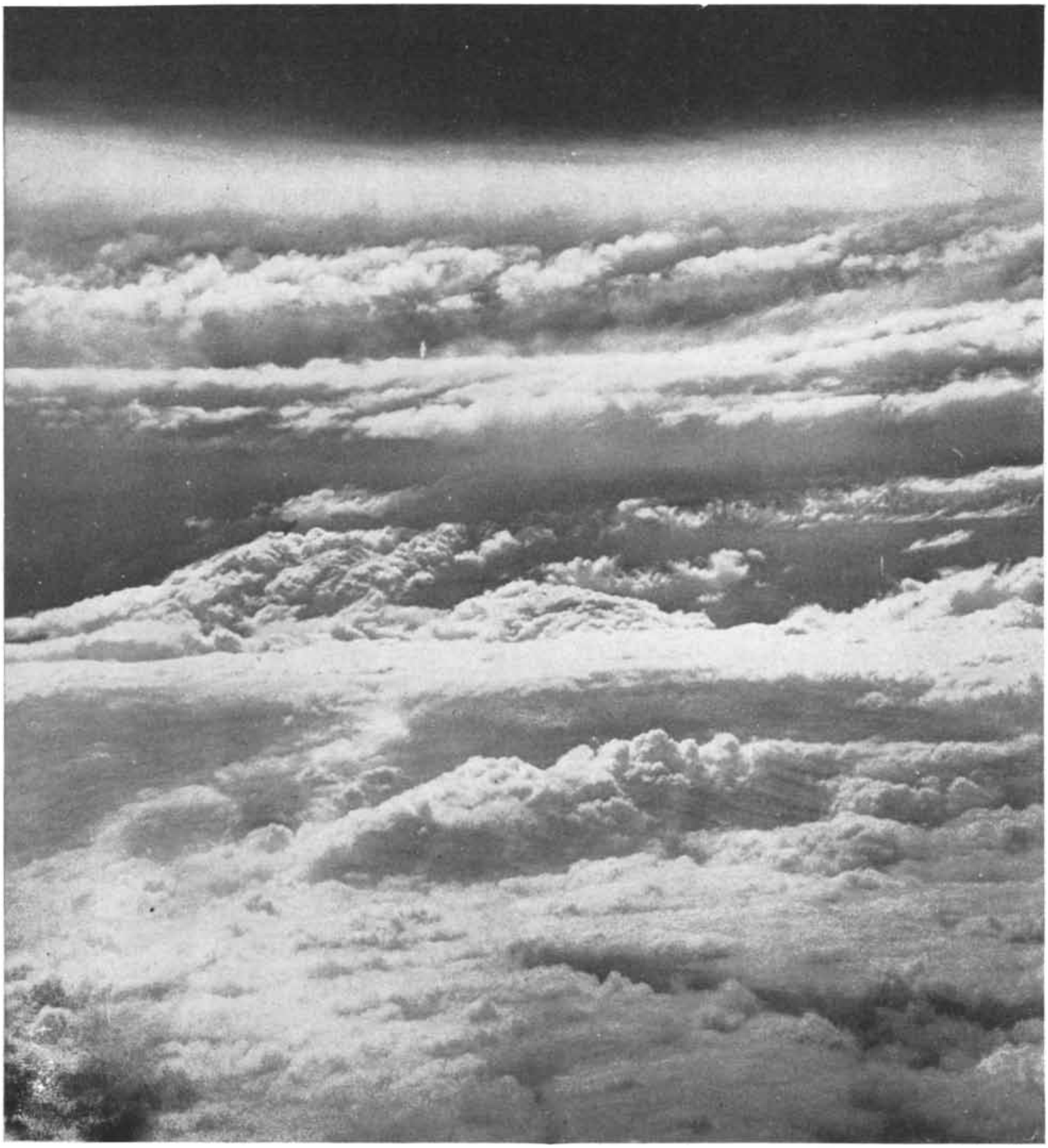
EASTERLY-WAVE CUMULUS CLOUDS are similarly represented. The trough of the wave is indicated by the heavy, curved vertical line. The wave destroys the inversion layer, permitting the clouds to ascend more than 20,000 feet and become thunderheads.

ricane. Here the air is falling instead of ascending, and, as it sinks, the increasing pressure of the surroundings squeezes and warms it. The air descending in the eye probably is thrown out again into the rain band at low levels by centrifugal force, so that more air falls in from the top. It seems that this downflow of warmed air is the ultimately essential condition for a hurricane. Without it the temperature of the core cannot reach the necessary levels and the winds cannot exceed about 45 miles per hour. But once an eye has been formed and its associated air-warming process has begun, the storm is on the way to developing the phenomenally low pressures characteristic of a hurricane. This is the "point of no return"; the storm will now start its baleful career—and acquire a girl's name. The wind velocities may rise to hurricane fury within a few hours; the closed central vortex takes over from the easterly wave as the dominant driving force of the air in its path.

Just how the eye is formed is still unknown. The question involves a whole

CENTER OF DEEP DISTURBANCE which failed to become a hurricane was photographed from the Woods Hole PBY in 1956. The clear area in the center suggested the eye of a hurricane in the process of formation. Puerto Rico lies beneath clouds on horizon.

complex of detailed studies: the structure of the air surrounding the storm, air flows, cloud formations, features of the upper atmosphere and probably many other factors. The various groups cooperating in the Weather Bureau's National Hurricane Research Project have undertaken such explorations. The Woods Hole Oceanographic Institution and the University of Chicago are jointly analyzing the entire history of an extraordinarily deep tropical disturbance of 1956 which did not develop into a hurricane. Although the research is still incomplete, preliminary results suggest that this storm kept a cold core even though it had a calm, "eyelike" central region. Apparently the moist air rising in the vortex wall flowed out of the core in a disorganized fashion and at relatively low levels. One or more of the links in the complex chain of events that makes a hurricane were missing. Just what these are we hope eventually to discover and relate in a physical model, connecting an evolving storm with the tropical atmosphere as a whole.



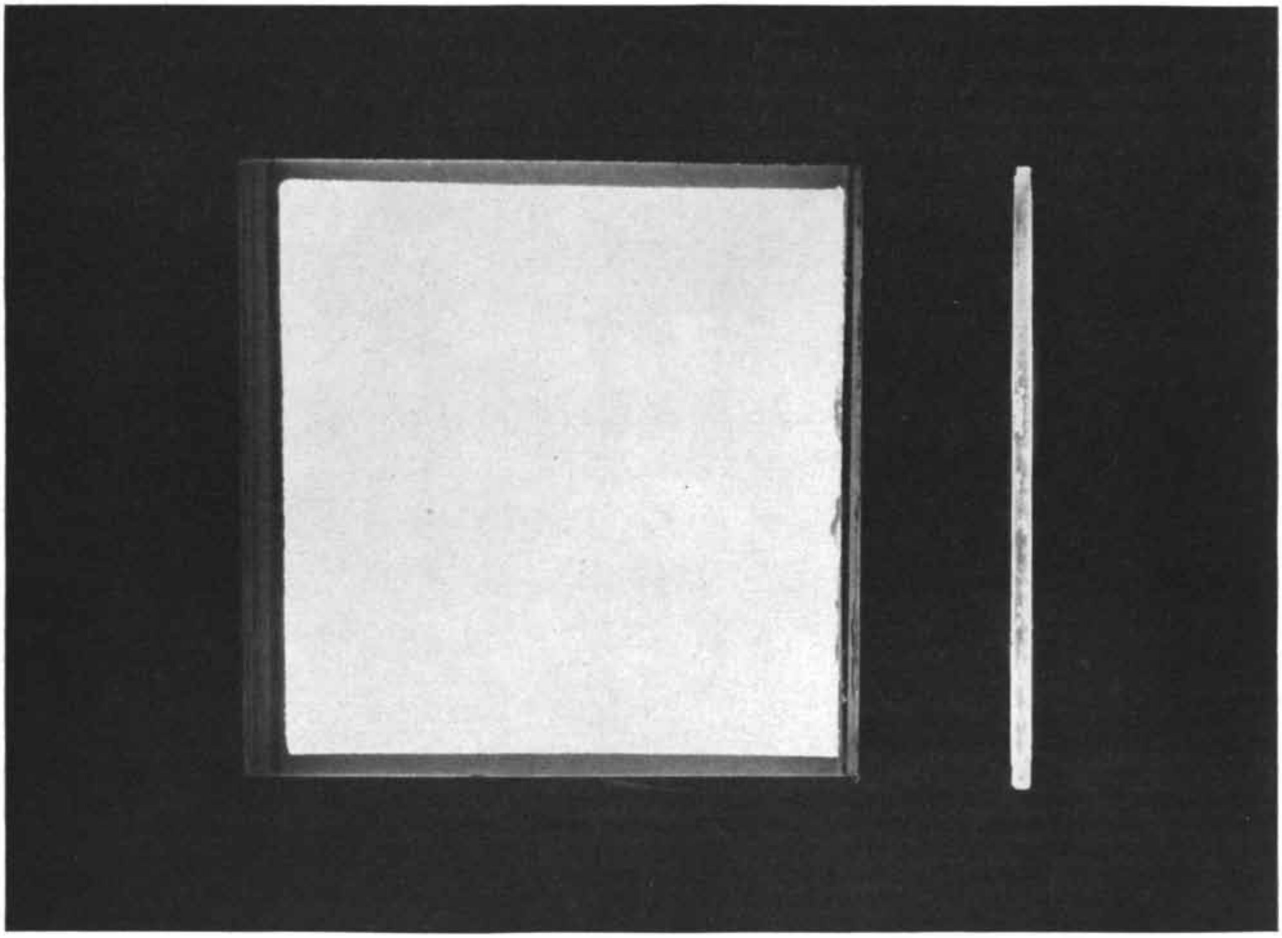
EYE OF PACIFIC HURRICANE Typhoon Marge was photographed in 1951 from a National Hurricane Research Project aircraft flying at 15,000 feet. The eye is surrounded by a wall of cloud which slopes away with altitude. Within the eye the sky is clear.

Electroluminescence

When a luminescent substance such as zinc sulfide is placed in an alternating electric field, it emits light. This effect makes possible thin illuminating panels and many other useful devices

by Henry F. Ivey

A new revolution in artificial lighting is in the making. Through most of human history man illuminated the darkness by means of a flame—progressing from the torch to the candle to the kerosene lamp. Within the last three quarters of a century our mode of living has been transformed by the incandescent and the fluorescent lamp. The innovation now under development is the luminescent panel. The prospect is that within a few years our houses and offices will begin to be lighted by luminous ceilings and walls. All sorts of attractive possibilities are opened up by this method of illumination. It will give us light of almost any color or brightness at will. Merely by turning a knob, we shall be able to bathe our rooms with rosy light on days of dreary skies, or with cool blue light when the sun is



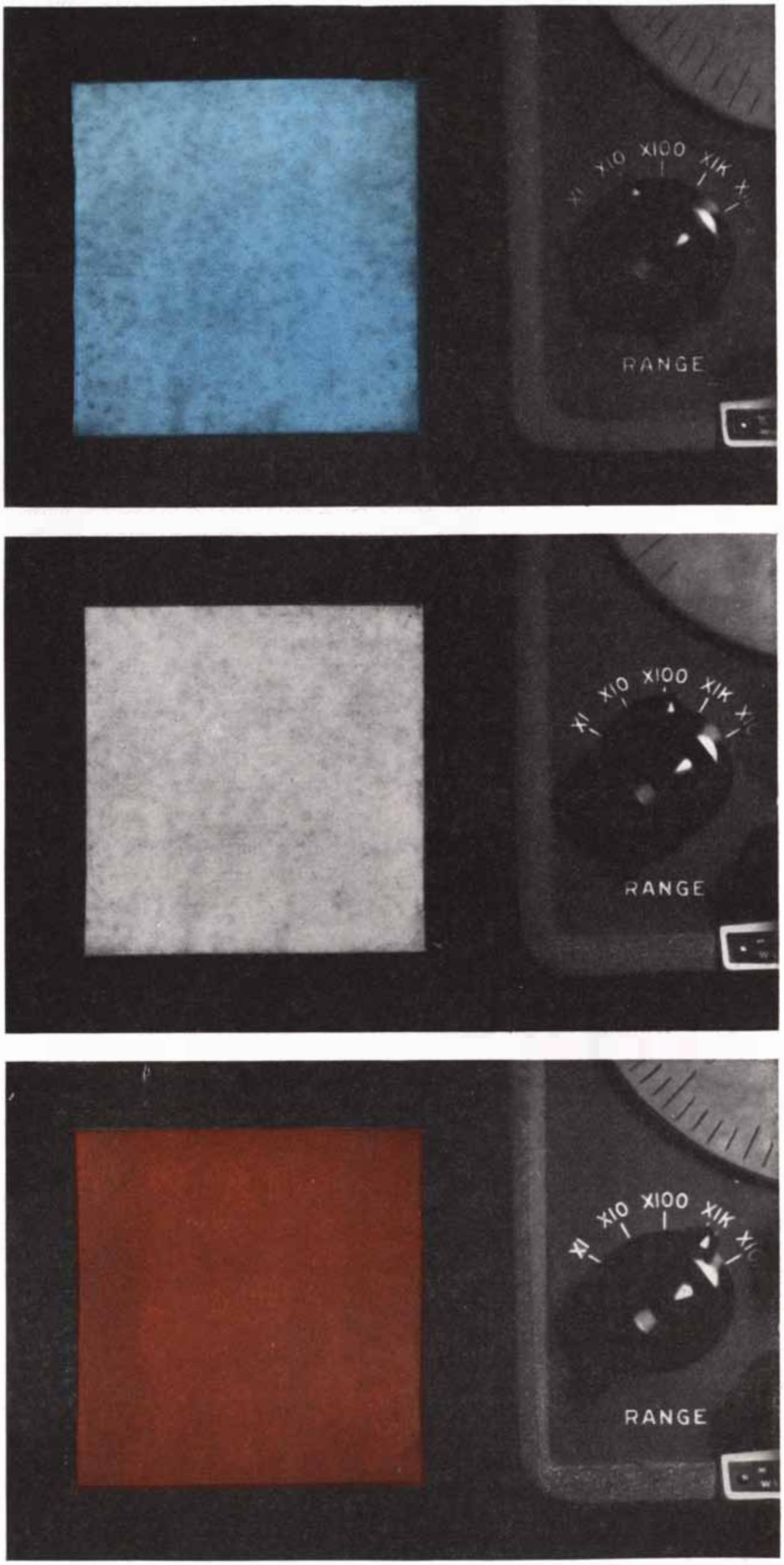
EXPERIMENTAL ILLUMINATING PANEL is seen from the front and side. The phosphor of the panel is embedded in a thin layer of nonconducting material. In back of this layer is a thin layer of opaque conducting material. In front of it is a film of conducting material on glass. The alternating voltage which causes the phosphor to glow is imposed across the conducting layers.

harsh. Night will be turned into day by curtains of light at our windows—draperies glowing with the golden shimmer of sunlight.

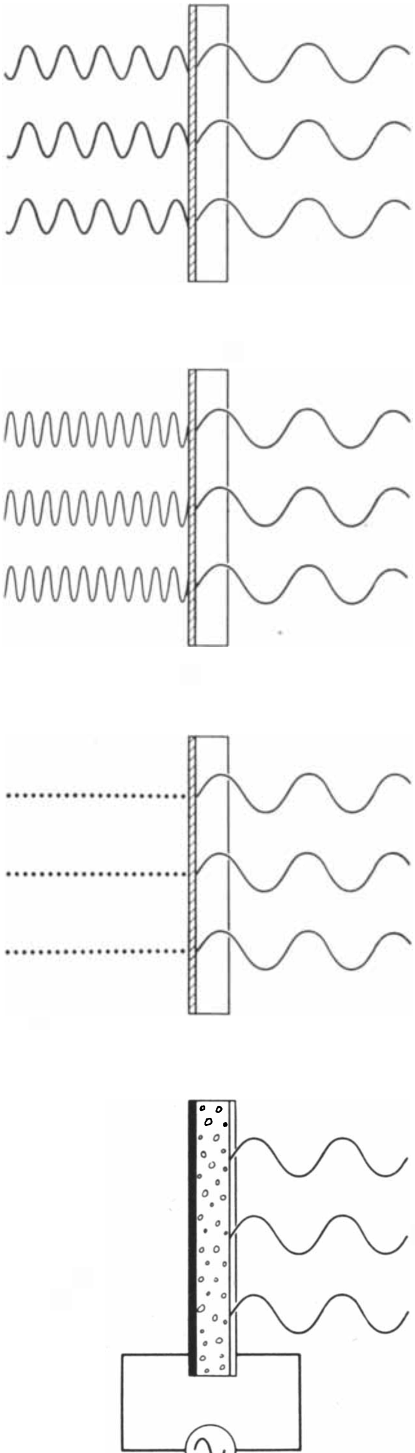
These, however, are only the more glamorous aspects of the phenomenon which is the subject of this article. Electroluminescence promises to revolutionize not only illumination but also techniques of picture-making. It can transform invisible radiations—ultraviolet, X-rays, cathode rays—into visible light. It may therefore improve X-ray photography and television, and introduce entirely new ways of forming pictures. But fully as interesting as its technological possibilities is the phenomenon itself. Electroluminescence is a new method of generating light. As such it gives us a new outlook on the behavior of energy and matter, in a realm which has recently become a cornucopia of useful and fundamental information—solid-state physics.

In a broad sense electroluminescence is not basically different from the luminescence we see in a fluorescent lamp, a fluoroscope or a television (cathode-ray) picture tube. In all of these devices the light is produced by exciting a phosphor. The difference among them lies in the agent used for excitation. In a fluorescent lamp the phosphor is excited by ultraviolet rays, produced in the tube by a gas discharge; in a fluoroscopic screen it is excited by X-rays; in a cathode-ray tube, by a beam of high-speed electrons. In the case of electroluminescence, the exciting agent is an alternating electric field. The phosphor, embedded in a thin layer of nonconducting material, is sandwiched between two layers of a material that conducts electricity. When an alternating voltage is applied to these outer layers (electrodes), it sets up an alternating electric field across the phosphor layer and causes the phosphor to emit light. From a practical point of view, the most important feature of this system is that it frees us from the confines of a tube or bulb in producing light. We can make light-emitting surfaces of any size or shape. Moreover, our "two-dimensional lamp" can be almost as thin as we please. The phosphor layer is only a few thousandths of an inch thick, and the outer layers of the sandwich can be fine wire meshes or films of a conducting substance (*e.g.*, tin oxide).

The fact that light could be generated by this method was discovered in 1936 by a Frenchman named George Destriau, and it is sometimes called the



COLOR OF PANEL CHANGES with frequency. Here the luminescent layer consists of two phosphors, one green and one red. The green phosphor is brighter at low frequencies; the red, at high frequencies. At intermediate frequencies the colors mix to produce white.



FOUR PHOSPHOR DEVICES are depicted schematically. In the fluorescent lamp (*top*) the phosphor (*hatched layer*) converts ultraviolet radiation (*wavy lines at left*) into light (*wavy lines at right*). In the fluoroscope (*second from top*) it converts X-rays into light. In the cathode-ray tube (*third*) it converts high-speed electrons (*dots*) into light. In the electroluminescent illuminating panel (*bottom*), the phosphor (*particles embedded in middle layer*) converts an alternating current (*wave symbol*) into light.

Destriau effect. He placed some zinc sulfide phosphors in an intense alternating field and made them glow—but so feebly that the light could be seen only in a dark room by eyes adapted to the darkness. The idea that phosphors could be excited by an electric field met with considerable doubt at first, but since 1950 Destriau's discovery has been followed up by intensive research, not only because it promises a new form of lighting but also because it is yielding new information about phosphors and the solid state.

The key to luminescence is the propensity of electrons in atoms to jump from one energy state to another. Upon absorbing a quantum of energy from some outside source, an electron jumps to a higher, or "excited," state. It may then jump back to its original state, re-emitting the absorbed energy. In a phosphor, part of this energy is emitted as light. But the process is complex, and certain conditions must be met to make the electron jumps produce light rather than merely heat or other radiations.

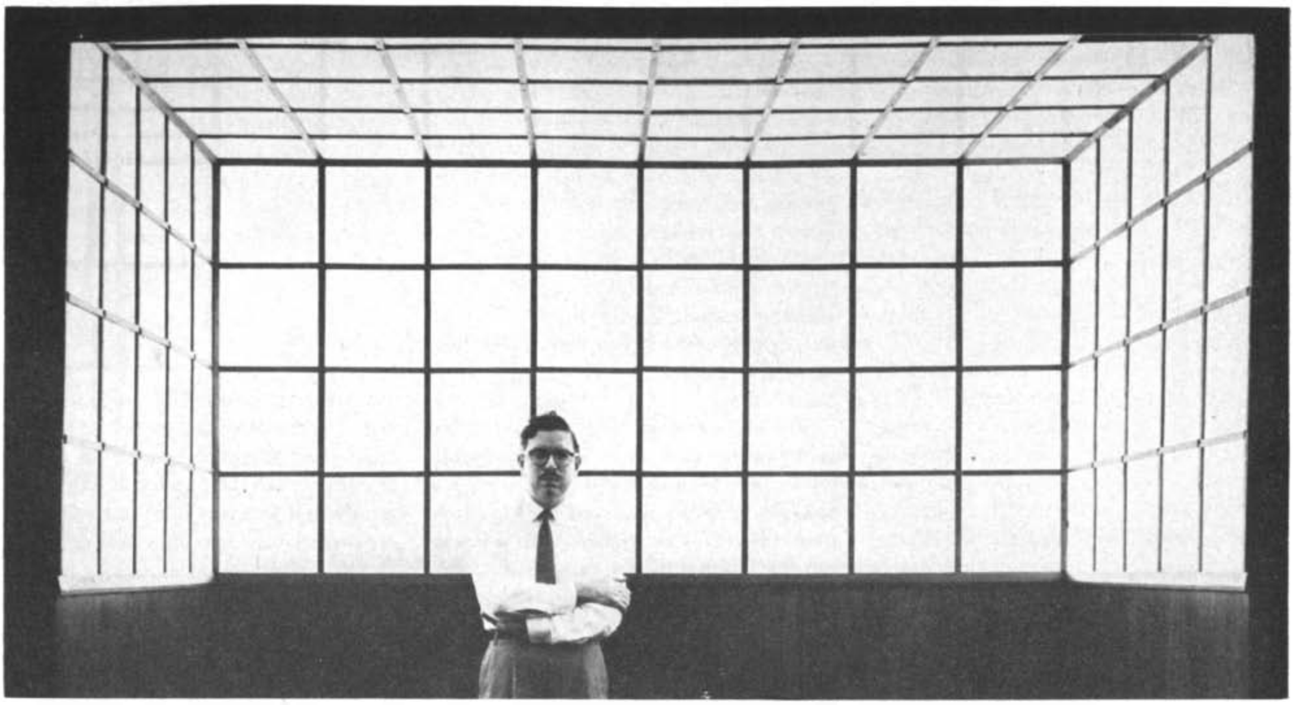
Here is a phosphor crystal, say zinc sulfide. Since its closely packed atoms interact with one another, we must think of its electrons as occupying a band of energy levels, instead of the single, sharply defined energy level of an electron in an isolated atom. Nevertheless, just as a single electron in an atom is permitted only certain energy levels and is forbidden any intermediate energies, so there is a forbidden band of energy values which cannot be occupied by any electrons of the zinc or sulfur atoms. When the crystal is unexcited, the lowest energy band is completely filled with electrons. If exciting energy is supplied to the crystal, some of the electrons will jump from this band across the forbidden band just above it into a permissible higher band. Now if an electron jumps back to the lowest band, it will emit energy—but not in the form of light. The quantum of energy required for a jump from one level to another depends on the width of the gap, and the size of the quantum determines the frequency, or wavelength, of the radiation emitted: the bigger the quantum, the higher the frequency. In this case the gap across the forbidden band is so wide that an electron jumping back to the lower band emits its energy at a frequency in the ultraviolet region rather than in the lower-frequency region of visible light.

But we can narrow the gap. Suppose we insert a new rung within the forbidden zone to shorten the step for the jumping electrons. We can accomplish this by introducing a few copper atoms into the zinc sulfide crystal. An energy level permissible to copper's electrons lies within the band forbidden to those of zinc and sulfur. If a copper electron is excited to a higher energy level, it leaves a vacancy which can be filled by an electron dropping from the higher band. The drop to this level is short enough—that is, the quantum is of the right size—to produce emission of light. The electron berths provided by the copper atoms are therefore called luminescence centers.

There are other holes, within the forbidden band and close to the higher energy band, into which electrons may fall. They are called traps, and are created by imperfections in the crystal or by chlorine atoms, which are introduced to control the number of copper atoms dissolved in the crystal. Electrons falling into traps generate only heat, but they are easily excited out of the traps and then can fall into empty luminescence centers, producing light.

The foregoing describes the mechanism of the more familiar types of luminescence, such as fluorescence. The ultraviolet rays in a fluorescent tube excite electrons contained in the phosphor to the higher permitted energy band, and the excited electrons then fall into empty luminescence centers. When we come to electroluminescence, the process is more indirect. The alternating electric field cannot kick electrons out of the centers directly. What it does is to accelerate free electrons, and these accelerated particles then knock electrons out of the luminescence centers, creating vacancies into which electrons can fall with emission of light. In practice, if the method is to produce much light, the phosphor has to be specially treated to increase the effectiveness of the electric field. Small particles of copper sulfide are introduced into the phosphor. Because copper sulfide is a good conductor, each of these particles concentrates and intensifies the electric field around it, and so enhances the acceleration of electrons.

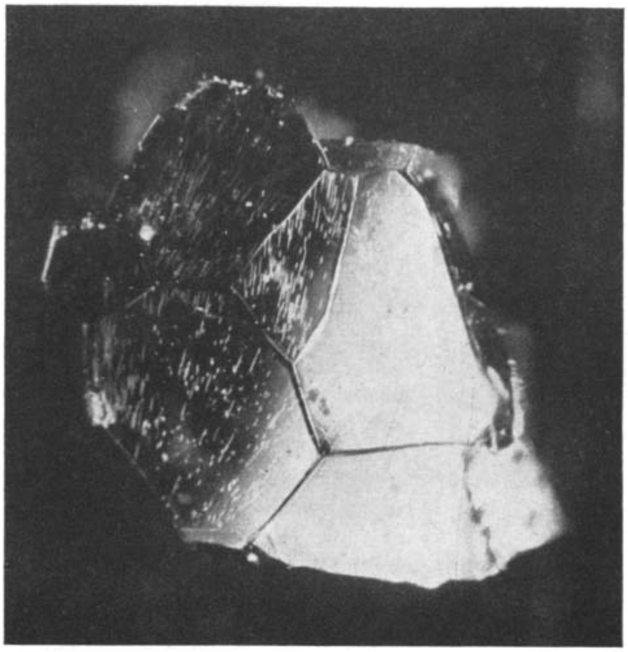
We get something of a picture of how the process works by setting up a mechanical analogy. Let us take a board pitted with holes like a Chinese checkerboard: deep holes represent luminescence centers and much shallower ones represent traps. Using marbles as electrons, we fill all the luminescence centers and some of the traps with electrons. The board is mounted on a fulcrum so that it

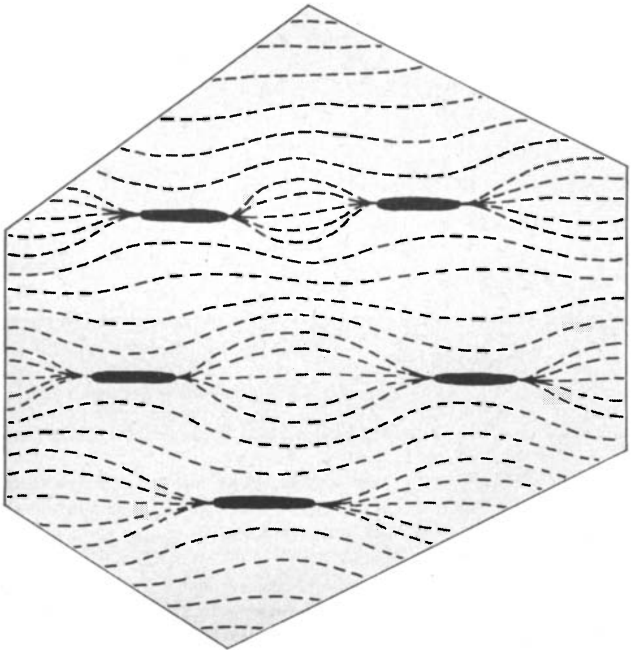


EXPERIMENTAL ROOM at the Bloomfield, N. J., plant of the Westinghouse Electric Corporation is illuminated with electroluminescent panels. The panels were made with zinc sulfide activated with copper. They operate at 400 volts and 3,000 cycles.

tilts from one side to the other like a seesaw: this represents the alternating electric field [*see drawings on page 45*].

Now suppose we look at one side of the board as it is tilted down. As the steepness of the tilt increases, marbles begin to roll out of the shallow traps; some hit marbles in luminescence centers and knock them out; soon there is an avalanche of marbles rolling down the surface of the board (representing the higher energy band). Then, after the board reaches its steepest tilt and starts back up again, the avalanche slows down. When the board returns to the horizontal position, the marbles stop rolling. They fall into traps, because there are no empty luminescence centers out near the periphery where they are concentrated. Many of the centers nearer the middle of the board are, however,





CRYSTALS OF CADMIUM SULFIDE, enlarged 200 times in the photograph at left, are shot through with needle-like dislocations of their crystal lattices. The diagram at right shows a crystal of zinc sulfide containing particles of copper sulfide in similar dislocations. Because copper sulfide is a good conductor, the particles distort and intensify an electric field (*broken lines*) around them.

unoccupied. Now the side of the board that we are watching begins to tilt upward. The marbles roll out of the traps and back toward the empty centers. They drop into these holes. The cycle is completed when the board again comes back to the horizontal position.

Meanwhile on the other half of the board the same thing has happened, but one half-cycle out of phase. Thus while luminescence centers are being emptied on one side of the board they are being filled on the other.

This is what happens around each local intensification of the electric field in a phosphor. The field, though not strong enough to dislodge electrons from luminescence centers, can free electrons from the traps and so start an avalanche. Once started, the avalanche excites many of the electrons out of the centers by means of collisions. It slows down as it reaches areas of low field strength. The electrons then fill nearby traps, only to be liberated again by the reverse build-up of the alternating field, which accelerates them back toward the empty centers. When electrons drop into the centers, they emit light.

The main problem in electroluminescence is to get enough output of light from the phosphor. There are two ways to step up its brightness: increase the voltage (*i.e.*, strengthen the electric field) or speed up the field's oscillating frequency. If we strengthen the field, we generate more light emission by emptying and refilling more luminescence centers in each cycle; if we increase the frequency (rock the board faster), we get the same result by emptying and refilling the centers more rapidly. But there are limits to both stratagems. Too strong a field will break down the insulating property of the phosphor layer; too short a cycle will not give the electrons time enough to emerge from their traps.

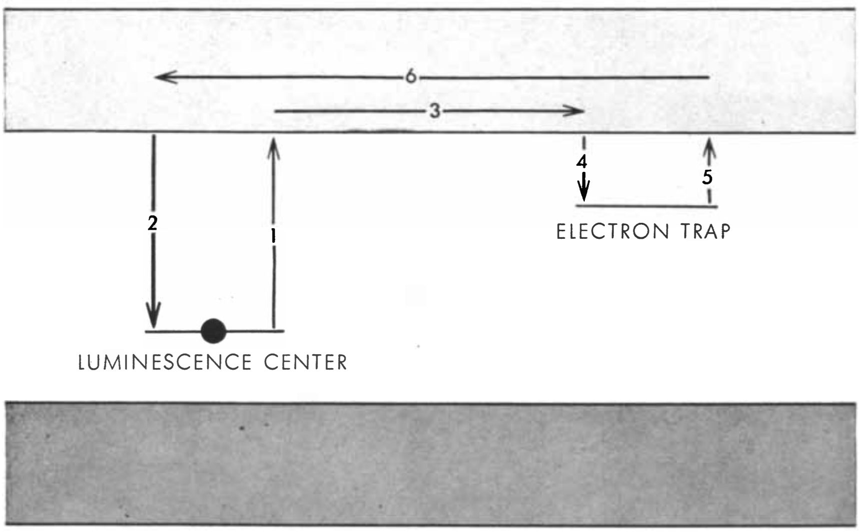
The highest brightness yet produced—achieved by exciting a green phosphor with a field at 20,000 cycles per second—is 2,500 lumens per square foot of phosphor area. This is brighter than a standard 40-watt fluorescent lamp. But it takes an inordinate amount of electric power, because the efficiency of the electroluminescent process is low. At 20,000 cycles per second electroluminescence yields only about one lumen per watt of applied power, whereas a fluorescent lamp gives 65 lumens per watt, and even an incandescent electric-light bulb (of 100 watts) yields 16 lumens per watt.

The reason for the low efficiency of electroluminescence is that the avalanching electrons spend most of their energy in collisions with atoms in the crystal: only a minority knock electrons out of luminescence centers. It has been found that the process behaves most efficiently when the applied electricity has a potential of a few hundred volts and a frequency of a few hundred cycles per second. The highest efficiency obtained so far is 12 lumens per watt. The aim of the workers on this problem is to raise the efficiency to about that of diffused fluorescent lighting—namely, about 30 lumens per watt.

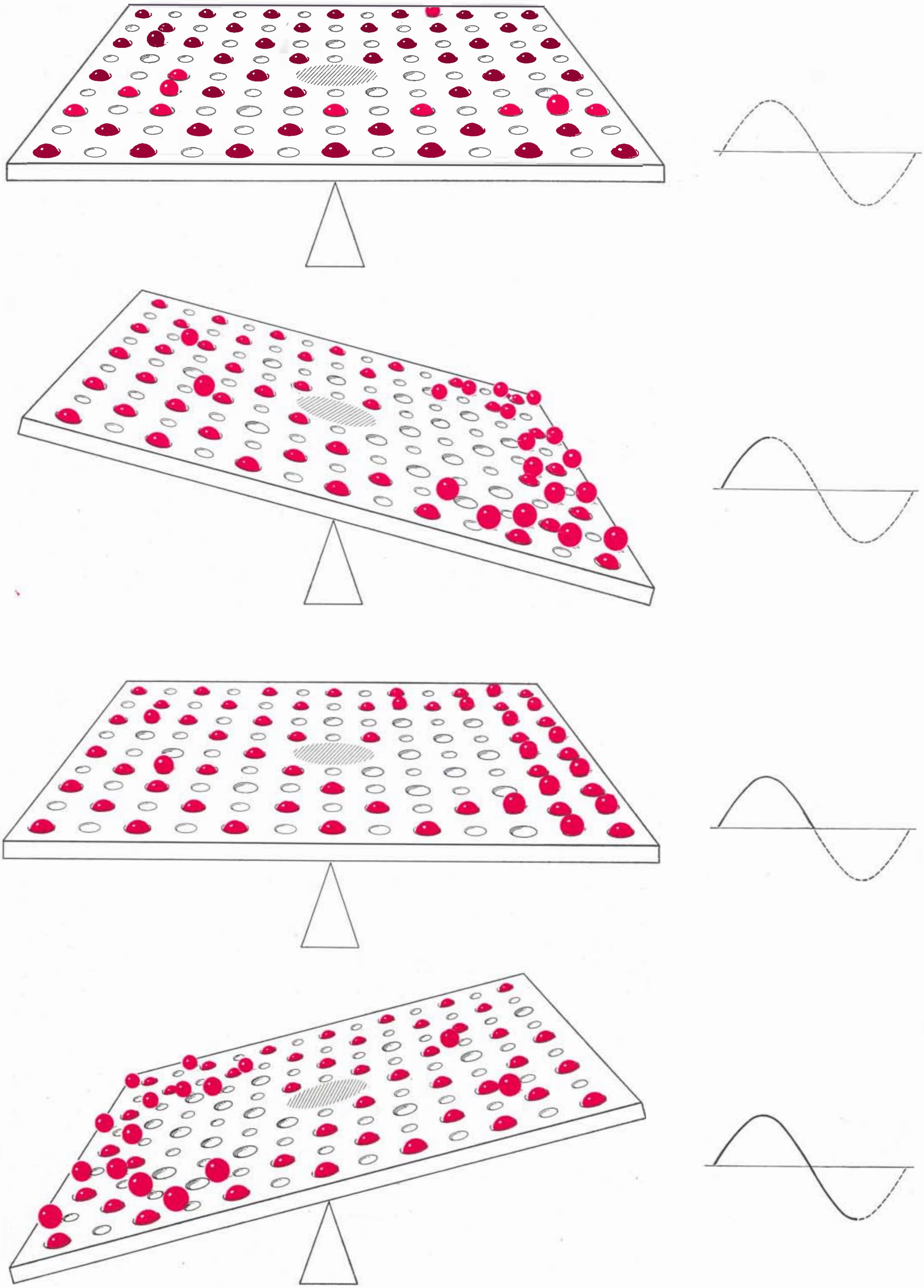
Until more effective materials are developed, electroluminescent lighting will require alternating electricity of considerably higher frequency than the 60-cycle current now supplied by power lines. For houses, small converters using transistors may serve to convert this current to the necessary frequencies. In a large office building it would be quite feasible to install a generator which would deliver power at frequencies around 1,000 cycles per second. The cost of such an installation would be offset by a great saving in the cubage of the building, because it would need only very thin ceilings, in place of the space now required for lamp fixtures. Whereas recessed fluorescent lamps, for instance, need a depth of 14 inches, electroluminescence would thin the ceiling down to less than one inch.

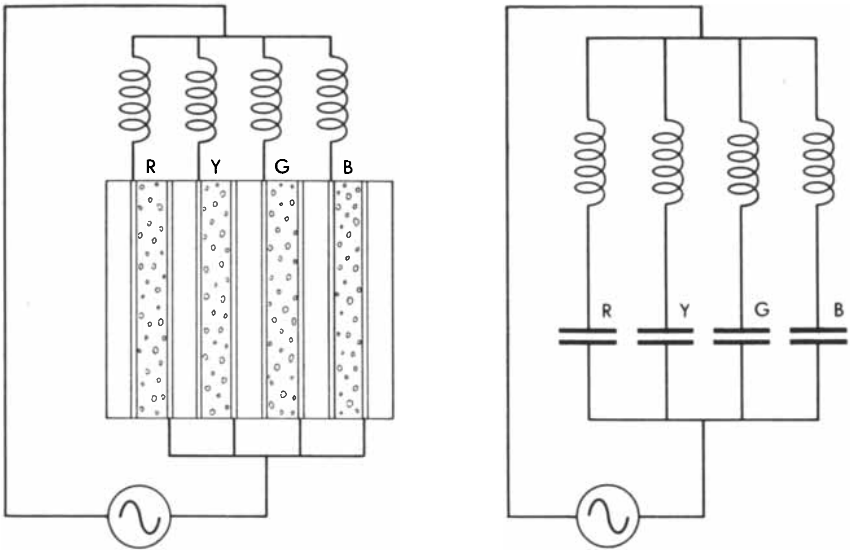
The fact that electroluminescent surfaces can take any size or shape provides an endless list of possibilities. Light might be built into walls, doors, stairs, balustrades, domes or any other elements of a building. It could be built into furniture and even into draperies, because the luminescent sheets can be made as flexible as cloth. And the color of the light could be changed instantly by tuning the applied electricity to a different frequency. The available colors depend on the substances introduced into the phosphor to provide luminescence centers. Copper gives blue or green. Manganese, whose electrons occupy an energy level closer to the upper energy band of the phosphor (*i.e.*, are

MECHANICAL ANALOGY discussed in the text of this article is depicted on the opposite page. The colored balls are electrons; the deep holes, luminescence centers; the shallow holes, electron traps. The hatched area in the center represents the copper sulfide introduced into the zinc sulfide crystal to intensify the electric field. The tilting of the board is an analogy for the alternation of the voltage, which is also represented by the curves at the far right.

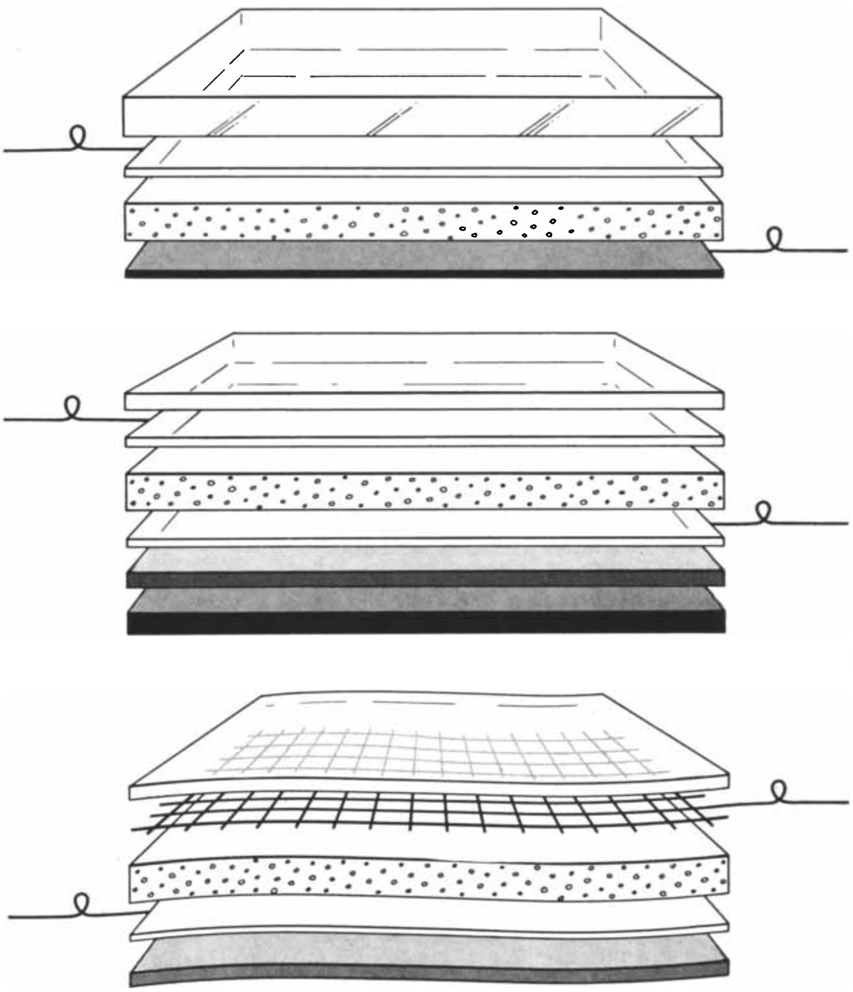


ENERGY BANDS of a zinc sulfide crystal are schematically depicted. At bottom is the band occupied by unexcited electrons; at top, the band occupied by excited electrons. Between the two is a "forbidden" band which cannot be occupied by electrons in a pure crystal. If an electron in such a crystal jumps from the lower band to the upper and falls back again, it may emit ultraviolet radiation or simply radiate heat. If copper atoms are introduced into the crystal, they form a luminescence center whose energy level is in the forbidden band. If an electron jumps from this level (1) and falls back again (2), it emits light. The electron can also wander through the crystal (3) and fall into an electron trap (4). Such a trap is created by an imperfection in the crystal or by chlorine atoms which are introduced to control the number of copper atoms. The electrons are easily dislodged from the trap (5) and can then fall back to the level of the luminescence center (6 *and* 2).





MULTICOLORED PANEL of one type is made by stacking red (R), yellow (Y), green (G) and blue (B) phosphors. Inductors are used to tune in each layer (*circuit at right*).



COMPLEX PANELS are dissected. Layers of the panel at top are, from top to bottom: glass, conducting coating, phosphor particles suspended in plastic, conducting coating. Layers of the cell in middle are: plastic, conducting coating, phosphor particles embedded in low-melting-point glass, reflecting enamel, metal base. Layers of the flexible panel at bottom are: plastic, wire mesh, phosphor embedded in plastic, conducting coating, plastic.

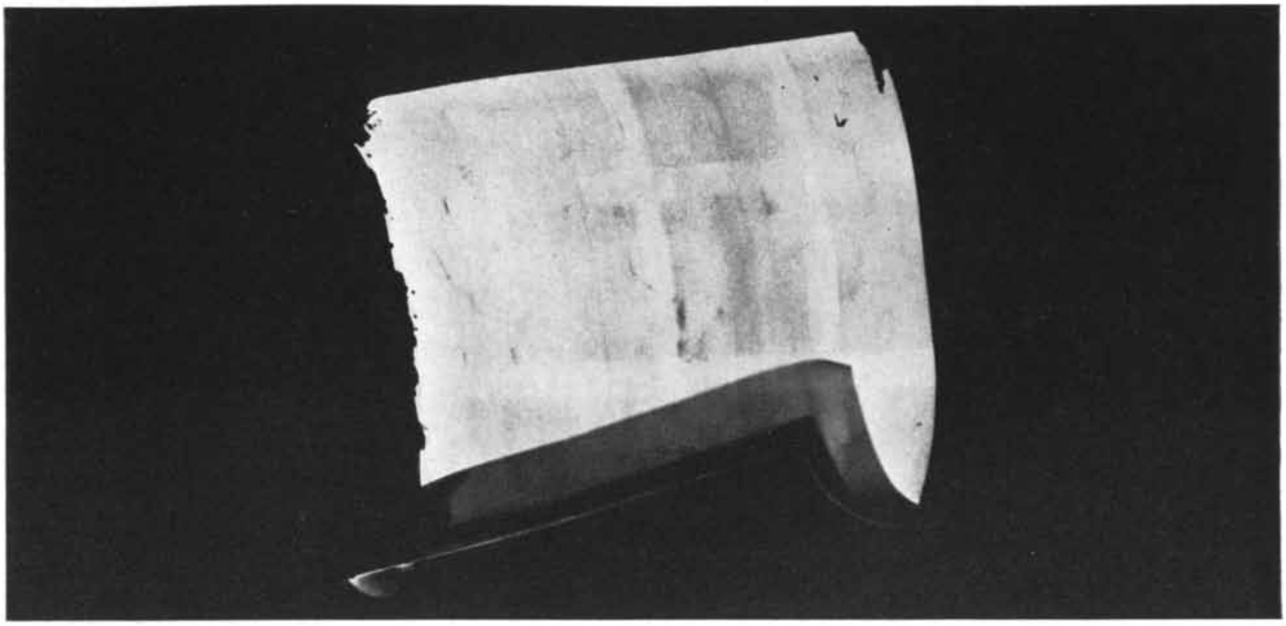
separated from it by a shorter gap), emits light of longer wavelengths. The selection of colors is made subject to control by frequency tuning by means of several methods, some of which involve combining different phosphors.

Let us see now how electroluminescence can form a picture. This can be accomplished by what is essentially a simple device. As the "camera"—the instrument for receiving the image of the object to be pictured—we can use a so-called photoconductor. This is a material whose ability to conduct electricity is increased by exposure to light or other radiation—the more intense the radiation falling upon it, the greater its conductivity. Suppose we back up a layer of photoconducting material with a layer of electroluminescent material and apply a voltage across the combination. If now we focus an image on the photoconducting side, the intensity of the light falling on each point will govern the voltage across the two layers at that spot. In other words, the photoconductor translates the light and dark parts of the picture into a pattern of varying voltage. In turn, this voltage pattern excites in equally varying degree the corresponding points in the phosphor on the other side of the sheet. The luminescent phosphor therefore displays the original image, as if it were projected on a screen. The interesting point is that even patterns formed by invisible radiations (acting upon the photoconductor) can be converted into visible pictures. Moreover, the device can amplify the "brightness" of the image picked up by the photoconductor. Thus it could, for example, display an X-ray picture many times more brightly than a fluoroscope can.

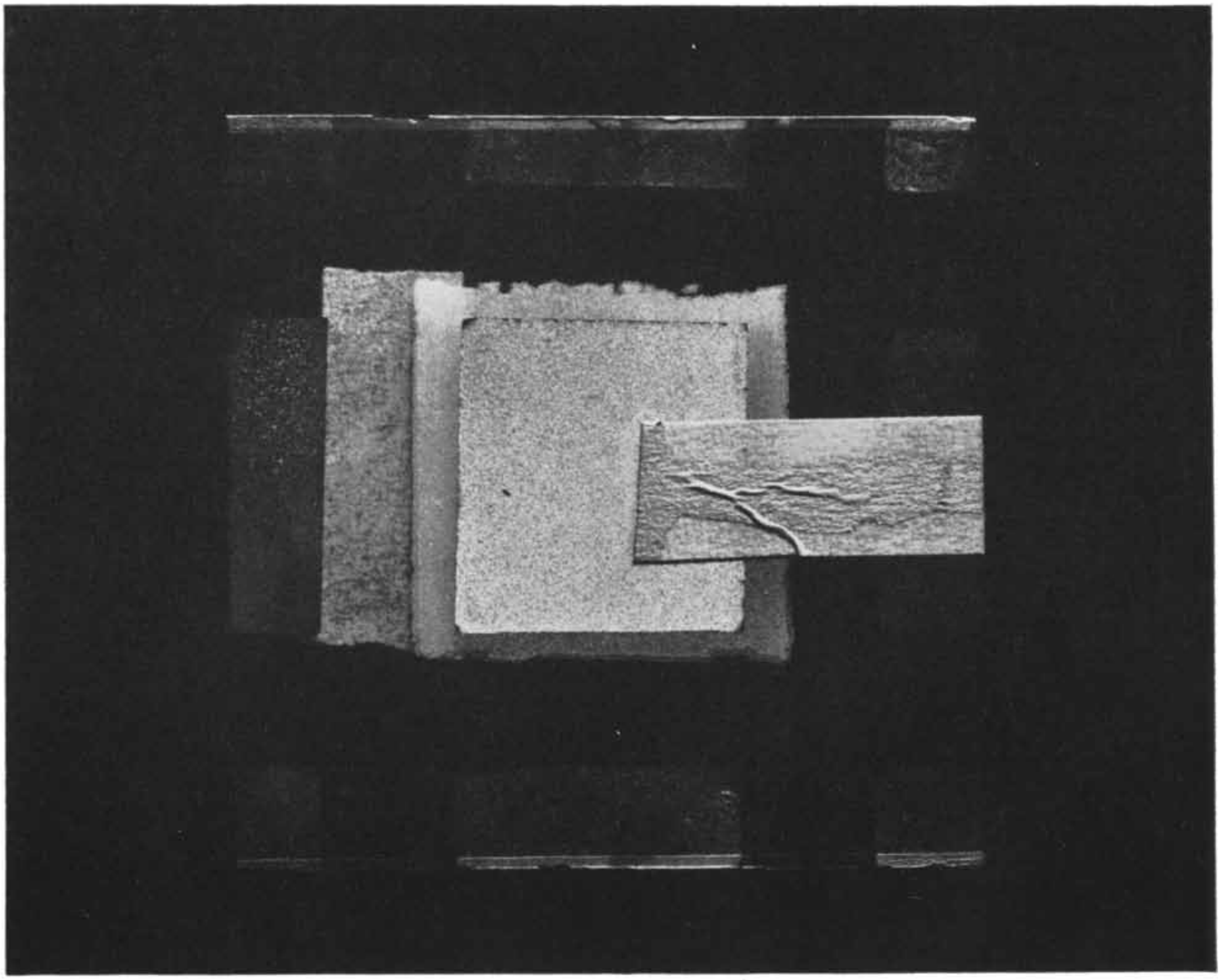
If we let the light emitted by the luminescent side feed back to the photoconducting side, we have a device for storing information: it stores a certain voltage even after the original stimulating signal has been removed. This compact form of storage could be useful for incorporation in electronic computing machines.

It seems possible that an electroluminescent screen could perform the functions of a cathode-ray tube; if so, we might eventually have television sets thin enough to be hung on the wall like a framed picture.

There are a number of problems to be solved before electroluminescence enters our daily lives, but the research laboratories working on them hope that, with luck, they will be solved in the next few years.



FLEXIBLE PANEL in this photograph was made by spraying a layer of phosphor suspended in a nonconducting material on a screen with 200 meshes to the inch and covering it with a layer of vaporized aluminum. Panel operates at 110 volts and 4,000 cycles.



TEST PANEL is built up on glass. The oblong at right is the connection of the square electrode beneath it. The larger square beneath the electrode is phosphor in plastic. The oblong at left is the connection of the other electrode, which is not visible.

How Fishes Swim

In which the speed of small fishes is measured in the laboratory and their power calculated. Similar observations in nature suggest that water may flow over a dolphin completely without turbulence

by Sir James Gray

The submarine and the airplane obviously owe their existence in part to the inspiration of Nature's smaller but not less attractive prototypes—the fish and the bird. It cannot be said that study of the living models has contributed much to the actual design of the machines; indeed, the boot is on the other foot, for it is rather the machines that have helped us to understand how birds fly and fish swim [see "Bird Aerodynamics," by John H. Storer; SCIENTIFIC AMERICAN, April, 1952]. But engineers may nevertheless have something to learn from intensive study of the locomotion of these animals. Some of their performances are spectacular almost beyond belief, and raise remarkably interesting questions for both the biologist and the engineer. In this article we shall consider the swimming achievements of fishes and whales.

Looking at the propulsive mechanism of a fish, or any other animal, we must note at once a basic difference in mechanical principle between animals and inanimate machines. Nearly all machines apply power by means of wheels or shafts rotating about a fixed axis, normally at a constant speed of rotation. This plan is ruled out for animals because all parts of the body must be connected by blood vessels and nerves: there is no part which can rotate freely about a fixed axis. Debarred from the use of the wheel and axle, animals must employ levers, whipping back and forth, to produce motion. The levers are the bones of its skeleton, hinged together by smooth joints, and the source of power is the muscles, which pull and push the levers by contraction.

The chain of levers comprising a vertebrate's propulsive machine appears in its simplest form in aquatic animals. Each vertebra (lever) is so hinged to its neighbors that it can turn in a single plane. In fishes the backbone whips from side to side (like a snake slithering along the ground), in whales the backbone undulates up and down. A swimming fish drives itself forward by sweeping its tail sidewise; as the tail and caudal fin are bent by the resistance of the water, the forward component of the resultant force propels the fish [*see drawing on page 50*]. As the tail sweeps in one direction, the front end of the body must tend to swing in the opposite direction, since it is on the opposite side of the hinge, but this movement is usually small—partly because of the high moment of inertia of the front end of the body and partly on account of the resistance which the body offers to the flow of water at right angles to its surface. Thus the head end of the fish acts as a fulcrum for the tail, operating as a flexible lever.

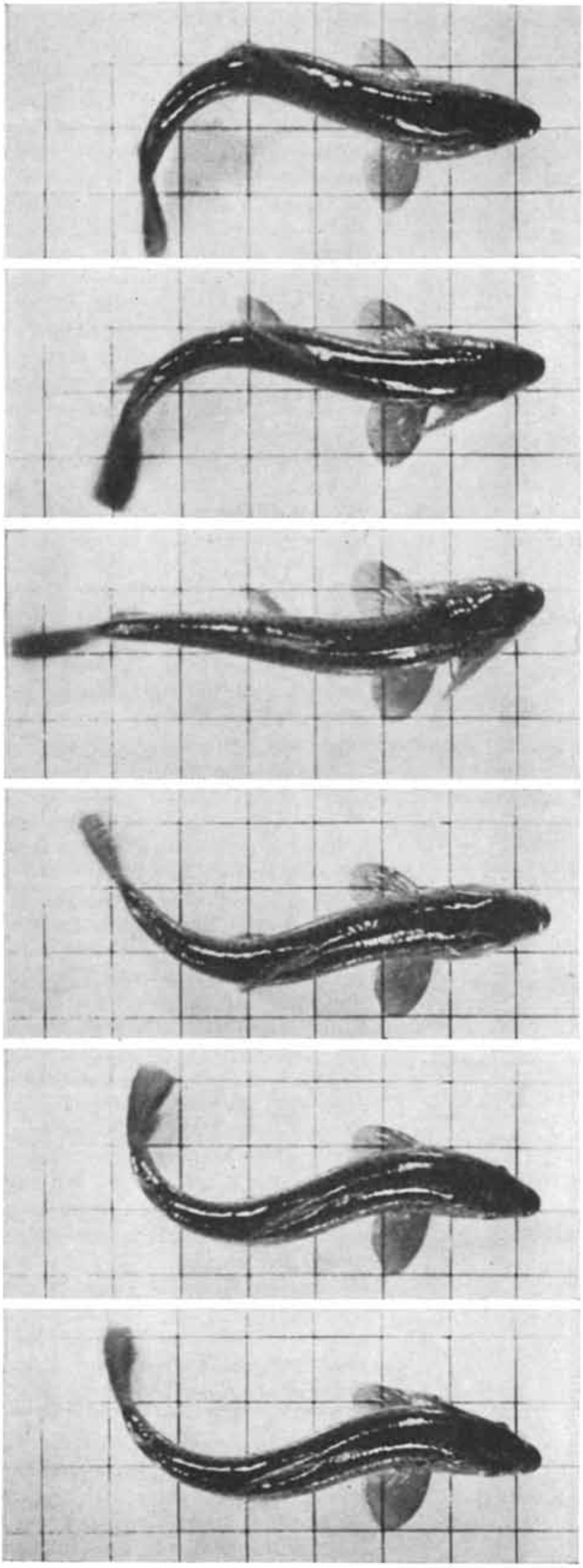
At the moment when the tail fin sweeps across the axis of propulsion, it is traveling rapidly but at a constant speed. During other phases of its motion the speed changes, accelerating as the tail approaches the axis and decelerating after it passes the axis. The whole cycle can be regarded as comparable to that of a variable propeller blade which periodically reverses its direction of rotation and changes pitch as it does so.

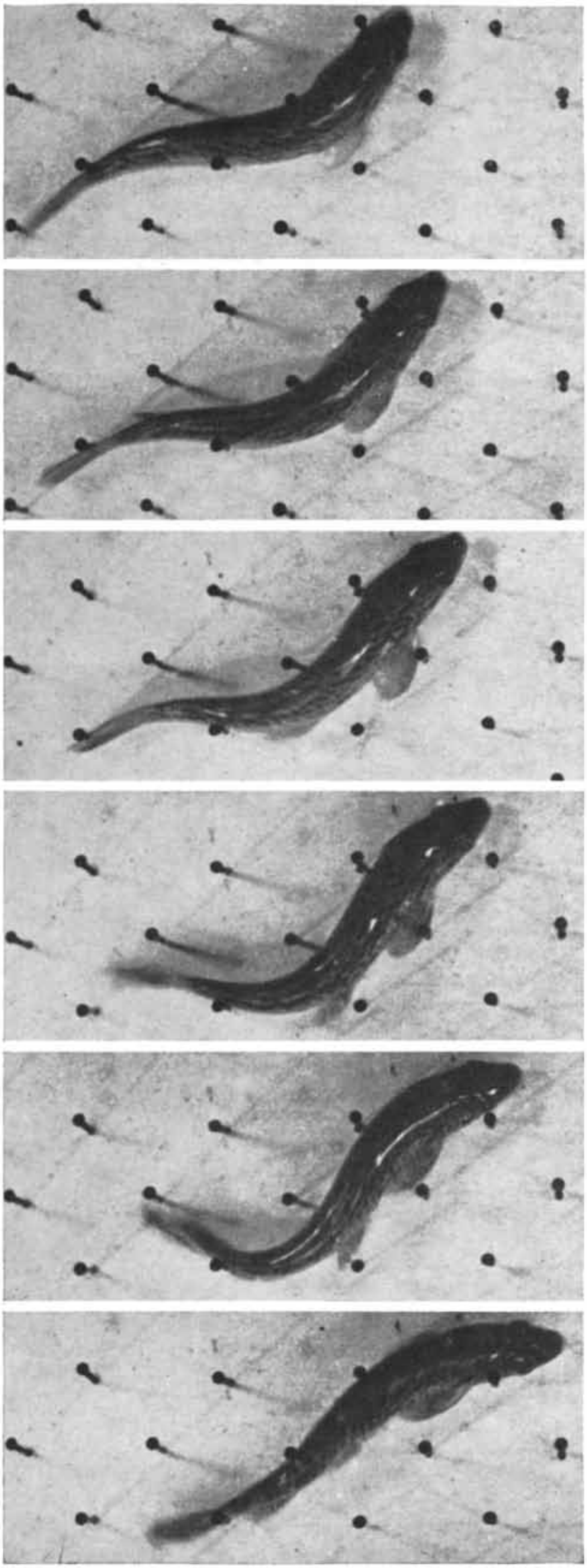
How efficient is this propulsion system? Can the oscillating tail of a fish approach in efficiency the steadily running screw propellers that drive a submarine, in terms of the ratio of speed to applied power? To attempt an answer to this question we must first know how fast a fish can swim. Here the biologist finds himself in an embarrassing position, for our information on the subject is far from precise.

As in the case of the flight of birds, the speed of fish is a good deal slower than most people think. When a stationary trout is startled, it appears to move off at an extremely high speed. But the human eye is a very unreliable instrument for judging the rate of this sudden movement. There are, in fact, very few reliable observations concerning the maximum speed of fish of known size and weight. Almost all the data we have are derived from studies of fish under laboratory conditions. These are only small fish, and in addition there is always some question whether the animals are in as good athletic condition as fish in their native environment.

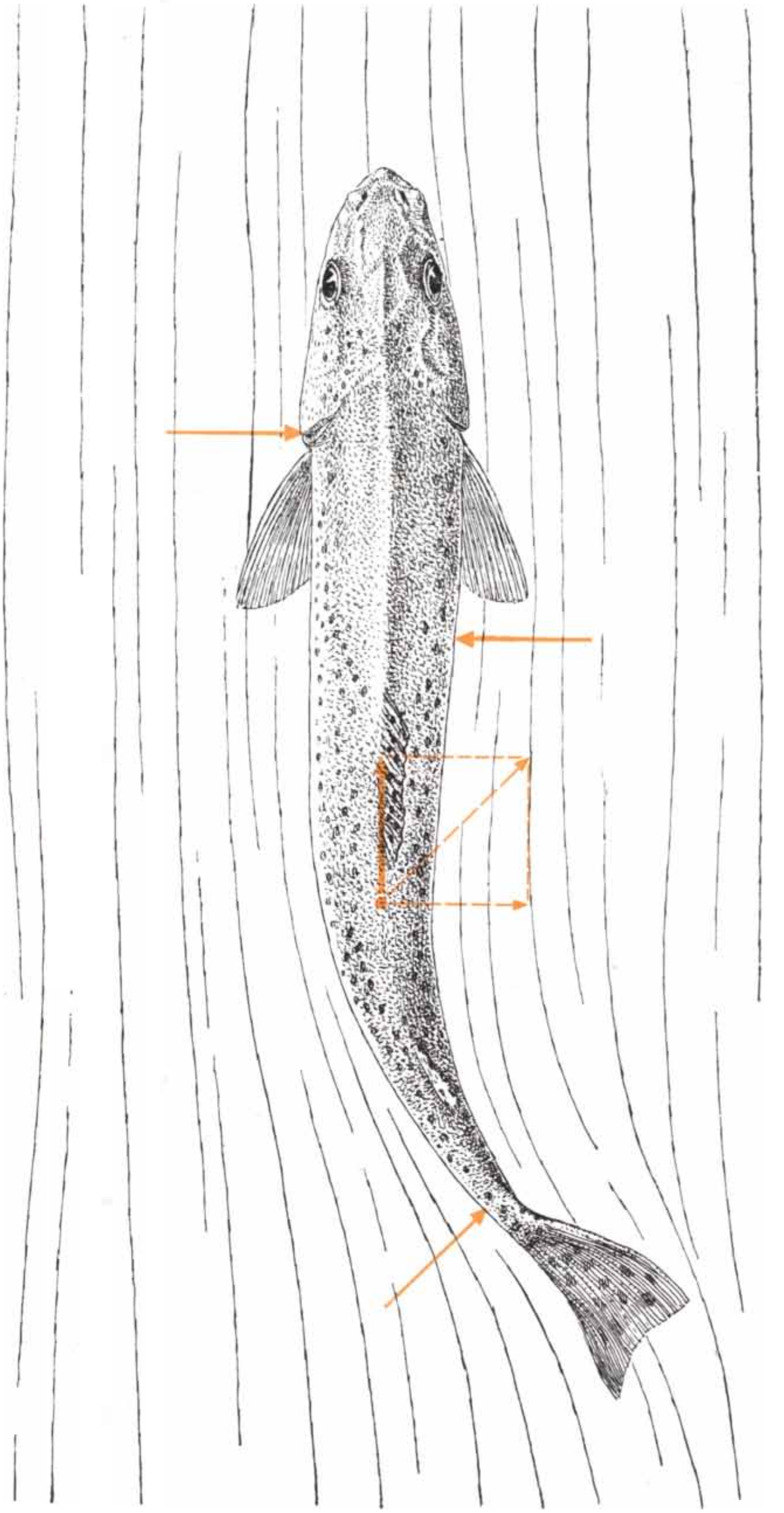
With the assistance of a camera, a number of such measurements have been made by Richard Bainbridge and others in our zoological laboratory at the University of Cambridge. They indicate that ordinarily the maximum speed of a small fresh-water fish is about 10 times the length of the fish's body per second; these speeds are attained only briefly at moments of great stress, when the fish is frightened by a sudden stimulus. A trout eight inches long had a maximum speed of about four miles per hour. The larger the fish, the greater the speed: Bainbridge found, for instance, that a trout one foot long maintained a speed of 6.5 miles per hour for a considerable period [*see table on page 52*].

It is by no means easy to establish a fair basis of comparison between fish of different species or between different-sized members of the same species. Individual fish—like individual human beings—probably vary in their degree of athletic fitness. Only very extensive observations could distinguish between average and "record-breaking" performances. On general grounds one would expect the speed of a fish to increase





HOW FISH EXERTS FORCE against its medium is illustrated by these two sequences of photographs showing trout out of the water. In the sequence at left the fish has been placed on a board marked with squares; it wriggles but makes no forward progress. In the sequence at right the fish has been placed on a board covered with pegs; its tail pushes against the pegs and moves it across the board.



HOW MEDIUM EXERTS FORCE on the fish is indicated by the arrows on this drawing of a trout. As the tail of the fish moves from right to left the water exerts a force upon it (*two diagonal arrows*). The forward component of this force (*heavy vertical arrow*) drives the fish forward. The lateral component (*broken horizontal arrow*) tends to turn the fish to the side. This motion is opposed by the force exerted by the water on sides of the fish.

with size and with the rapidity of the tail beat. Bainbridge's data suggest that there may be a fairly simple relationship between these values: the speed of various sizes of fish belonging to the same species seems to be directly proportional to the length of the body and to the frequency of beat of the tail—so long as the frequency of beat is not too low. In all the species examined the maximum frequency at which the fish can move its tail decreases with increase of length of the body. In the trout the maximum observed frequencies were 24 per second for a 1.5-inch fish and 16 per second for an 11-inch fish—giving maximum speeds of 1.5 and 6.5 miles per hour respectively.

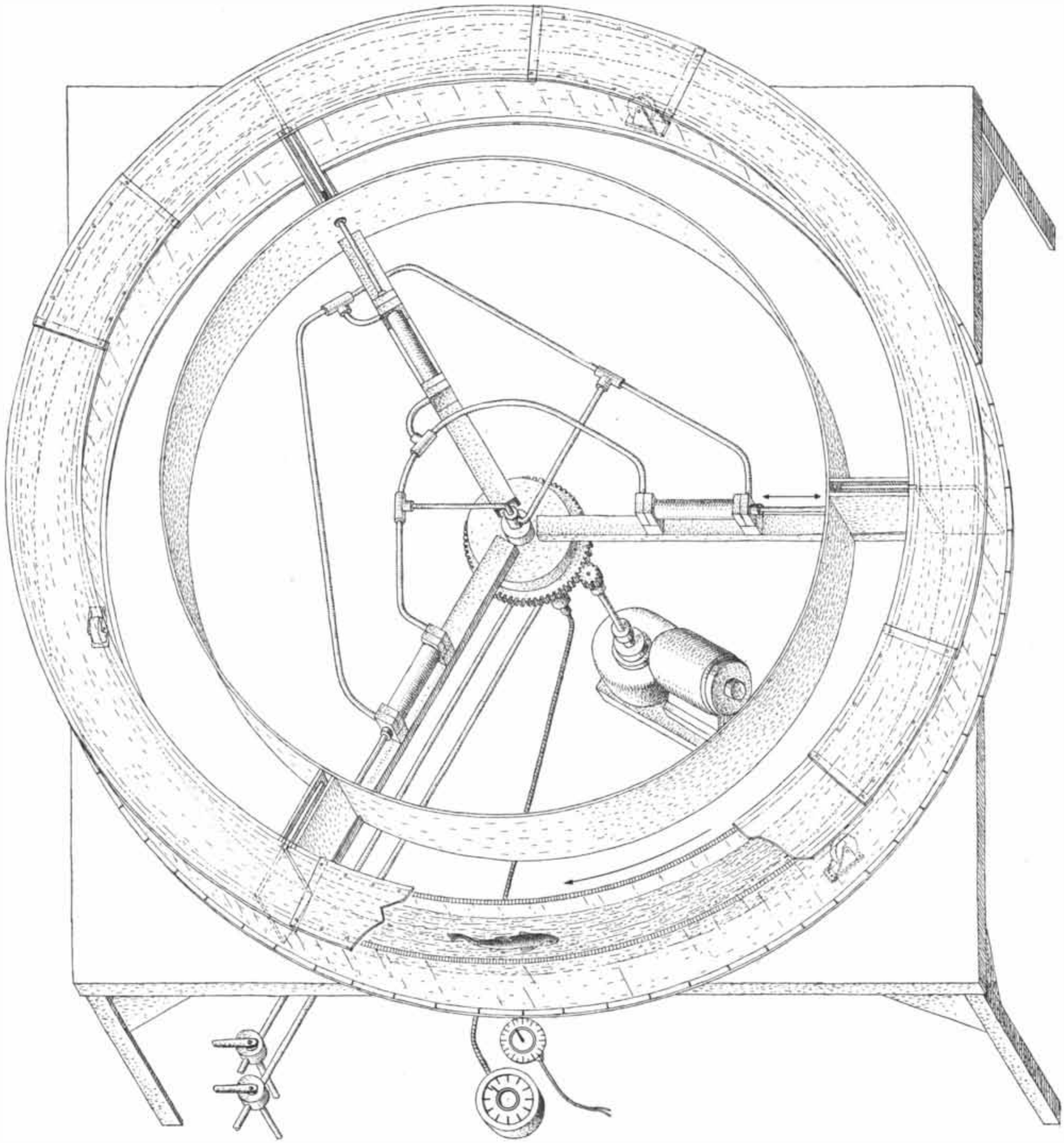
The data collected in Cambridge indicate a very striking feature of fish movement. Evidently the power to execute a sudden spurt is more important to a fish (for escape or for capturing prey) than the maintenance of high speed. Some of these small fish reached their maximum speed within one twentieth of a second from a "standing" start. To accomplish this they must have developed an initial thrust of about four times their own weight.

This brings us to the question of the muscle power a fish must put forth to reach or maintain a given speed. We can calculate the power from the resistance the fish has to overcome as it moves through the water at the speed in question, and the resistance in turn can be estimated by observing how rapidly the fish slows down when it stops its thrust and coasts passively through the water. It was found that for a trout weighing 84 grams the resistance at three miles per hour was approximately 24 grams—roughly one quarter of the weight of the fish. From these figures it was calculated that the fish put out a maximum of about .002 horsepower per pound of body weight in swimming at three miles per hour. This agrees with estimates of the muscle power of fishes which were arrived at in other ways. It seems reasonable to conclude that a small fish can maintain an effective thrust of about one half to one quarter of its body weight for a short time.

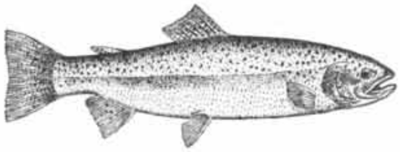
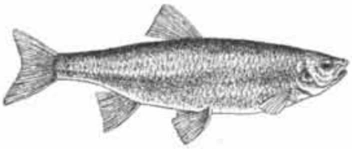
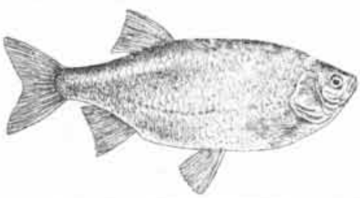
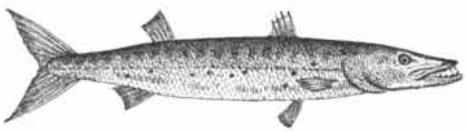
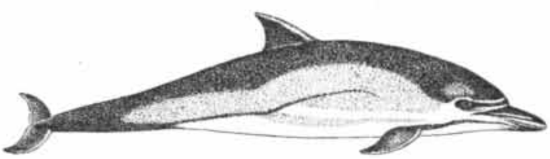
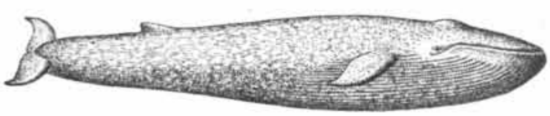
As we have noted, in a sudden start the fish may exert a thrust several times greater than this—some four times its body weight. The power required for its "take-off" may be as much as .014 horsepower per pound of total body weight, or .03 per pound of muscle. The fish achieves this extra force by a much more violent maneuver than in ordinary swimming. It turns its head end sharply to one side and with its markedly flexed tail executes a wide and powerful sweep against the water—in short, the fish takes off by arching its back.

This sort of study of fishes' swimming performances may seem at first sight to be of little more than academic interest. But in fact it has considerable practical importance. The problem of the salmon industry is a case in point. The seagoing salmon will lay eggs only if it can get back to its native stream. To reach its spawning bed it must journey upriver in the face of swift currents and sometimes hydroelectric dams. In designing fish-passes to get them past these obstacles it is important to know precisely what the salmon's swimming capacities are.

Contrary to popular belief, there is little evidence that salmon generally surmount falls by leaping over them. Most of the fish almost certainly climb the falls by swimming up a continuous sheet of water. Very likely the objective of their



SPEED OF FISHES WAS MEASURED in this apparatus at the University of Cambridge. The fish swims in a circular trough which is rotated by the motor at right center. The speed of the trough is adjusted so that the swimming fish is stationary with respect to the observer. The speed of the fish is then indicated on the speedometer at bottom. Above the speedometer is a clock. When the apparatus is started up, the water is made to move at the same speed as the trough by doors which open to let the fish pass.

	SPECIES	LENGTH (FEET)	MAXIMUM OBSERVED SPEED (FEET PER SECOND)	(MILES PER HOUR)	RATIO OF MAXIMUM SPEED TO LENGTH
	TROUT	.656 .957	5.552 10.427	3.8 6.5	8.5 11
	DACE	.301 .594 .656	5.229 5.552 8.812	3.6 3.8 5.5	17.8 9 13.5
	PIKE	.529 .656	6.850 4.896	4.7 3.3	13 7.5
	GOLDFISH	.229 .427	2.301 5.552	1.5 3.8	10.3 13
	RUDD	.730	4.240	2.9	6
	BARRACUDA	3.937	39.125	27.3	10
	DOLPHIN	6.529	32.604	22.4	5
	WHALE	90	33	20	.33

SPEED OF FISHES IS LISTED in this table. The speed of the first five fishes from the top was measured in the laboratory; that of the barracuda, dolphin and whale in nature. The barracuda is the fastest known swimmer. Whale in the table is the blue whale.

leap at the bottom of the fall is to pass through the fast-running water on the surface of the torrent and reach a region of the fall where the velocity of flow can be negotiated without undue difficulty. The brave and prodigious leaps into the air at which spectators marvel may well be badly aimed attempts of the salmon to get into the "solid" water!

A salmon is capable of leaping about six feet up and 12 feet forward in the air; to accomplish this it must leave the water with a velocity of about 14 miles per hour. The swimming speed it can maintain for any appreciable time is probably no more than about eight miles per hour. Accurate measurements of the swimming behavior of salmon in the neighborhood of falls are badly needed—and should be possible to obtain with electronic equipment.

At this point it may be useful to summarize the three main conclusions that have been reached from our study of the small fish. Firstly, a typical fish can exert a very powerful initial thrust when starting from rest, producing an acceleration about four times greater than gravity. Secondly, at times of stress it can exert for a limited period a sustained propulsive thrust equal to about one quarter or one half the weight of its body. Thirdly, the resistance exerted by the water against the surface of the moving fish (*i.e.*, the drag) appears to be of the same order as that exerted upon a flat, rigid plate of similar area and speed. Fourthly, the maximum effective power of a fish's muscles is equivalent to about .002 horsepower per pound of body weight.

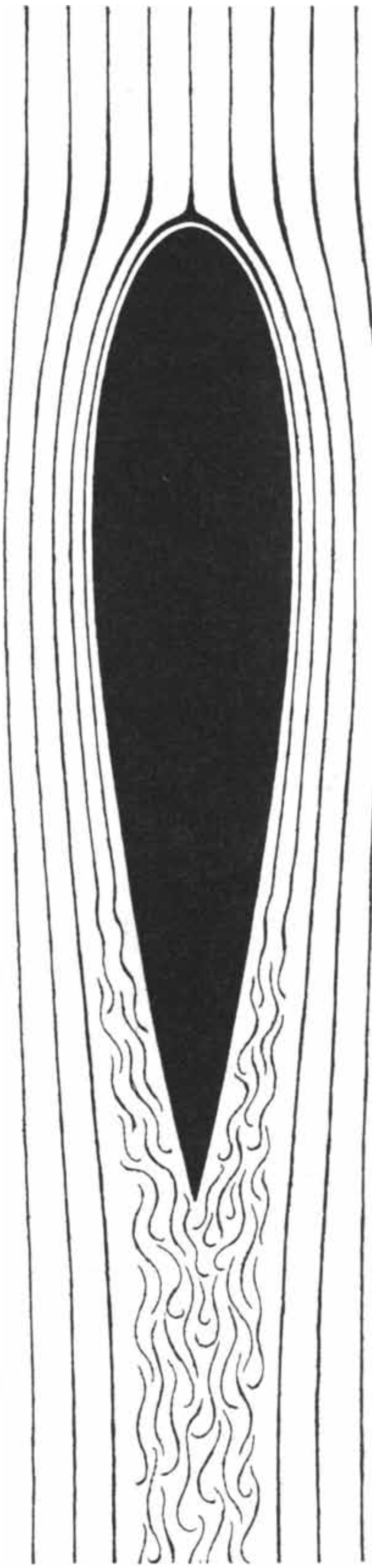
Such is the picture drawn from studies of small fishes in tanks. It has its points of interest, and its possible applications to the design of fish-passes, but it poses no particularly intriguing or baffling hydrodynamic problems. Recently, however, the whole matter of the swimming performance of fishes was given a fresh slant by a discovery which led to some very puzzling questions indeed. D. R. Gero, a U. S. aircraft engineer, announced some startling figures for the speed of the barracuda. He found that a four-foot, 20-pound barracuda was capable of a maximum speed of 27 miles per hour! This figure not only established the barracuda's claim to be the world's fastest swimmer but also prompted a new look into the horsepower of aquatic animals.

A more convenient subject for such an examination is the dolphin, whose attributes are somewhat better known than those of the barracuda. (The only essential difference between the propulsive machinery of a fish and that of a dolphin, small relative of the whale, is that the dolphin's tail flaps up and down instead of from side to side.) The dolphin is, of course, a proverbially fast swimmer. More than 20 years ago a dolphin swimming close to the side of a ship was timed at better than 22 miles per hour, and this speed has been confirmed in more recent observations. Now assuming that the drag of the animal's body in the water is comparable to that of a flat plate of comparable area and speed, a six-foot dolphin traveling at 22 miles per hour would require 2.6 horsepower, and its work output would be equivalent to a man—of the same weight as the dolphin—climbing 28,600 feet in one hour! This conclusion is so clearly fantastic that we are forced to look for some error in our assumptions.

Bearing in mind the limitations of animal muscle, it is difficult to endow the dolphin with much more than three tenths of one horsepower of effective output. If this figure is correct, there must be something wrong with the assumption about the drag of the animal's surface in the water: it cannot be more than about one tenth of the assumed value. Yet the resistance could have this low value only if the flow of water were laminar (smooth) over practically the whole of the animal's surface—which an aerodynamic or hydrodynamic engineer must consider altogether unlikely.

The situation is further complicated when we consider the dolphin's larger relatives. The blue whale, largest of all the whales, may weigh some 100 tons. If we suppose that the muscles of a whale are similar to those of a dolphin, a 100-ton whale would develop 448 horsepower. This increase in power over the dolphin is far greater than the increase in surface area (*i.e.*, drag). We should therefore expect the whale to be much faster than the dolphin, yet its top speed appears to be no more than that of the dolphin—about 22 miles per hour. There is another reason to doubt that the whale can put forth anything like 448 horsepower. Physiologists estimate that an exertion beyond about 60 or 70 horsepower would put an intolerable strain on the whale's heart. Now 60 horsepower would not suffice to drive a whale through the water at 20 miles per hour if the flow over its body were turbulent, but it would be sufficient if the flow were laminar.

Thus we reach an impasse. Biologists are extremely unwilling to believe that



LAMINAR AND TURBULENT FLOW are depicted in this diagram of a streamlined body passing through the water. The smooth lines passing around the body indicate laminar flow; the wavy lines, turbulent flow.

fishes or whales can exert enough power to drive themselves through the water at the recorded speeds against the resistance that would be produced by turbulent flow over their bodies, while engineers are probably equally loath to believe that laminar flow can be maintained over a huge body, even a streamlined body, traveling through the water at 20 miles per hour.

Lacking direct data on these questions, we can only speculate on possible explanations which might resolve the contradiction. One point that seems well worth re-examining is our assumption about the hydrodynamic form of the swimming animal. We assumed that the resistance which the animal (say a dolphin) has to overcome is the same as that of a rigid body of the same size and shape moving forward under a steady propulsive force. But the fact of the matter is that the swimming dolphin is not a rigid body: its tail and flukes are continually moving and bending during each propulsive stroke. It seems reasonable to assume, therefore, that the flow of water over the hind end of the dolphin is not the same as it would be over a rigid structure. In the case of a rigid model towed through the water, much of the resistance is due to slowing down of the water as it flows past the rear end of the model. But the oscillating movement of a swimming animal's tail accelerates water in contact with the tail; this may well reduce or prevent turbulence of flow. There is also another possibility which might be worth investigation. When a rigid body starts from rest, it takes a little time for turbulence to develop. It is conceivable that in the case of a swimming animal the turbulence never materializes, because the flukes reverse their direction of motion before it has an opportunity to do so.

It would be foolish to urge these speculative suggestions as serious contributions to the problem: they can only be justified insofar as they stimulate engineers to examine the hydrodynamic properties of oscillating bodies. Few, if any, biologists have either the knowledge or the facilities for handling such problems. The questions need to be studied by biologists and engineers working together. Such a cooperative effort could not fail to produce facts of great intrinsic, and possibly of great applied, interest.

DOLPHINS (called porpoises by seamen) were photographed by Jan Hahn as they swam beside the bow of the *Atlantis*, research vessel of the Woods Hole Oceanographic Institution, in the Gulf of Mexico. The speed of these dolphins was about 11 miles per hour.

Kodak reports on:

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Out to 25μ

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Though the production scale is still modest, we would like to try supplying it in molded shapes to manufacturers determined to outdo us on optical systems employing it, or in short rods to those who want to beat us even at molding it.

Potential competitors at either level and other friends are most cordially invited to submit inquiries about Kodak Selenium Glass *to Eastman Kodak Company, Apparatus and Optical Division, Rochester 4, N. Y.*

17 years have gone by

The great Ivan Pavlov—you learned about him in Psychology 1—did more than found behaviorism. The old boy lit the light that set off a chain of more than 100 patents on preparations that would get medicines safely through the stomach and on into the intestine.

This year expiration befell our U. S. 2,196,768, which was one of them.

In the dull monotone affected by the patent bar, this document droned on and on about "a medicament surrounded by an enteric film or layer of a cellulose derivative which contains a dicarboxylic acid radicle [*sic*] and which contains free carboxyl groups . . . " etc., etc., etc. In Examples VII and VIII and Claim 10 appeared cellulose acetate-phthalate. That was it. That was our baby.

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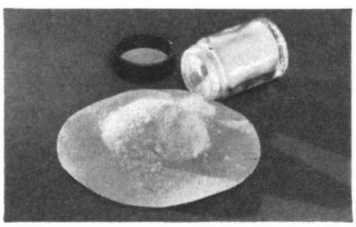
The reason CAP has been able to do mankind a little good is that it's just extremely resistant to gastric action, most susceptible to the hydrolytic influences of intestinal esterases, and quite independent of the assumption that the contents of the human upper intestine are reliably alkaline. Nor does it lean on the controversial assumption that the stomach empties at a reliable rate. Tablets coated with CAP have shown no signs of disintegration after seven days in a continuously agitated artificial gastric juice. In the same investigation in simulated intestinal juice at pH 6.9 rupture took place in 70 to 75 minutes, while at pH 8.5 all tablets disintegrated within 50 minutes.

The bill for the cellulose ester research that led to CAP has been paid. Now if you want to make an enteric-coated medicament with it, your lawyers can forget about our lawyers. All we can do is hope you will buy Eastman *Cellulose Acetate Phthalate, wherein about half of the original glucose hydroxyl groups are acetylated and about a quarter are phthalylated with one of the two carboxyls of phthalic acid. It is sold by Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company) and looks like this:*



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This fall we celebrate the 25th anniversary of our entry into commercial plastics (as distinguished from plastics for photographic film base, which we have been in since 1889). Hooray.

If you share our elation over the occasion, you will permit us to send you a plastic (*Tenite Butyrate*) commemorative medallion depicting one of the first U. S. injection molding machines. This heraldic device marks the historic fact that injection molding of plastics became an art of mankind through our exploitation of the discovery that cellulose acetate, mixed with a plasticizer, could be squirted hot. Hooray!

Not only that, but we stand out from the crowd of plastics makers in another way, too. We deplore limitations on the number of color standards in the trade, for we know the joy that the human race takes in its color vision.

Long live *Kodachrome*, *Kodacolor*, *Ektachrome*, *Ektacolor*, and *Eastman Color Films!* Also *Chromspun Acetate Yarn!*

The chromaticity diagram of the International Commission on Illumination—long may it wave!

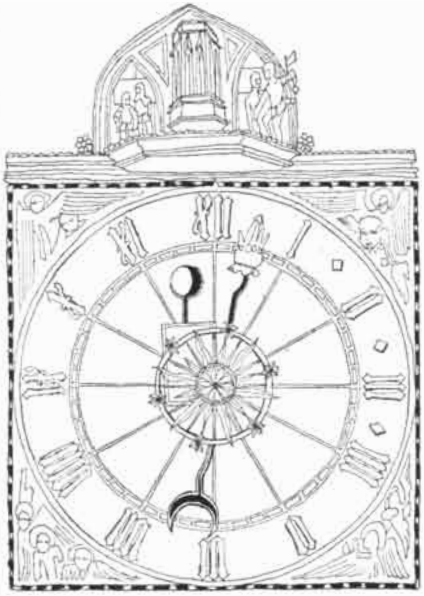
Long live those gallant fellows of ours who spend their 8-to-5 lives exploring its mathematical properties and conclude that the normal eye is capable of about two million distinguishably different color sensations, half of which are possible as colors of actual objects!

Long live the automotive genius who decides just how much difference from any of the 38,000 extant colors in sturdy *Tenite Acetate*, extra tough *Tenite Butyrate*, and warmly soft *Tenite Polyethylene* it will take to create a certain effect in your wife's mind when she sneaks a peek into the 1959 model while waiting in the showroom for the service department to make its estimate on overhauling the old heap!

For a reprint of a very recent paper of ours that tells how to build an electronic digital tristimulus integrator that attaches to a recording spectrophotometer and reads off ICI co-ordinates for any color, write Eastman Kodak Company, Research Laboratories, Rochester 4, N. Y. For the commemorative medallion, or for any conceivable color effect in Tenite Plastics, *which are, frankly, the aristocratic family of the plastics age, write Eastman Chemical Products, Inc., Kingsport, Tenn. (Subsidiary of Eastman Kodak Company).*

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

Kodak
TRADE MARK



Fallout

The views of U. S. scientists on fallout were aired and debated in eight full days of hearings before the Joint Congressional Committee on Atomic Energy last month. In general the witnesses agreed that the atomic weapons tests carried out so far have not released enough radioactivity to menace the world's present or future population to any substantial degree. But there was disagreement among the scientists on how dangerous further testing would be.

The argument turned chiefly on the question of "permissible" levels of exposure and the effects of very small amounts of radiation. Is there a "threshold" dose of radioactivity below which there is no biological damage? If so, tests could continue with safety until that level was approached. But if the effects merely decrease proportionately with the dose, then any permissible figure is a compromise that admits some damage. The hearings dealt with three effects of radiation: hereditary defects caused by mutation of reproductive cells; leukemia and bone cancer caused by strontium 90, and shortening of life caused by irradiation of the body as a whole. The witnesses generally agreed that radiation causes some genetic damage however small the world-wide dose. But they split on the other two effects. Some believed that there was almost certainly a threshold; others, including most of the geneticists, argued that even small doses could produce body damage.

The latest estimates on the total fallout to date were reported by workers engaged in the Atomic Energy Commission's project for determining its amount and effect, which is called "Project Sunshine." They said that significant levels of general radioactivity have accumulated only in the immediate vicinity of the test sites. In some inhabited areas in Nevada a person living constantly out of doors would have been exposed to four roentgens of radiation over the past four years—about equal to the average dose a person accumulates from natural background radiation in 30 years. In the rest of the U. S. and the world the concern is not with general radioactivity but with strontium 90. Merrill Eisenbud, manager of the AEC's New York Operations Office, told the Committee that about one million curies of the isotope have now fallen on the earth and another 2.4 million are still floating in the stratosphere and will have fallen by 1970. The distribution is not uniform: more has fallen in mid-northern latitudes than elsewhere. In the northeastern U. S. the soil now contains 20 millicuries per square mile, and will have 45 in 1970, assuming no further testing.

The concentrations in food (mainly milk) and in human bones resulting from this soil contamination are measured in "sunshine units." A sunshine unit is one micromicrocurie (a millionth of a millionth of a curie) of strontium 90 per gram of calcium. The present maximum permissible concentration of strontium 90 for atomic energy workers is 1,000 sunshine units. For the population as a whole, the National Academy of Sciences has recommended a maximum of 100, and perhaps 50 for children. The British Medical Research Council has said that an average concentration above 10 sunshine units in children would be cause for concern.

Concentrations of strontium 90 in human bone samples are being measured by J. Laurence Kulp of Columbia University. He estimates that the average child under the age of four in North America has seven tenths of a sunshine unit in his bones, and that the world average in children up to four is half a unit. Adults have only about one seventh as much. Kulp predicted that without further bomb tests the concentration in the bones of children will rise to three sunshine units by 1970, and if tests continue at the present rate it will go up to 24 sunshine units in 50 years.

William F. Neuman of the University

of Rochester calculated that, assuming 50 sunshine units was the maximum permissible concentration, no more than 2.2 megatons of fission explosions should be set off annually from now on; this would balance the radioactive decay of strontium 90 against new production at a tolerable level. The average rate of fission explosions during the past five years has been about 10 megatons a year.

Shields Warren, former director of the AEC's Division of Biology and Medicine, argued that a 10-megaton rate was safe and that this might not be "an absolute upper limit." Atomic Energy Commissioner Willard F. Libby and others agreed with him.

The witnesses' assessment of damage from fallout radiation depended on their opinion as to a threshold. Those who, like Warren, believe there is a threshold for bodily injury, held that there will be essentially no damage from a testing program continuing at the present rate. On the other hand, Walter Selove of the University of Pennsylvania estimated that current levels of strontium 90 might increase the deaths from leukemia and bone cancer by 1 per cent. This would mean an additional 100 deaths per year in the U. S. He quoted a British study which predicted that the tests already held would eventually cause 50,000 deaths throughout the world. James F. Crow, a University of Wisconsin geneticist, estimated that, at the present rate of exposure, the next generation of parents over the world will bear 8,000 gross defectives because of fallout.

Many witnesses testified that if all the bomb-testing nations turned to "clean" thermonuclear bombs, employing comparatively little fissionable fuel, the fallout hazard would become negligible. But Alvin C. Graves, test director at the Nevada proving grounds, told the Committee that there could be no such thing as a completely clean bomb: some fission energy would always be required to set off the fusion process.

The hearings were conducted under the chairmanship of Representative Chet Holifield of California. In a recent speech in the House of Representatives Holifield said: "The Atomic Energy Commission has continually given out assurances that we had nothing to worry about and yet we find, using testimony from their own experts, that there is rea-

son to worry. . . . Obviously some control and limitation of weapons testing is now mandatory!"

Nobelium

Another synthetic element has been made, extending the list of elements to 102. The new element was named nobelium, because it was produced at the Nobel Institute for Physics in Stockholm.

Nobelium has a half-life of 10 to 12 minutes. About 40 atoms of the element have been brought into fleeting existence, and from their behavior in an ion-exchange column and their mode of decay, some properties of the element have been determined.

It was made by bombarding curium (element 96) with nuclei of carbon atoms in the cyclotron at the Nobel Institute. This instrument, capable of being tuned to accelerate preferentially carbon ions with a quadruple positive charge, produces an unusually intense beam of these nuclei.

The creation and identification of nobelium was a cooperative effort of an international team of scientists consisting of Paul R. Fields and Arnold M. Friedman of the Argonne National Laboratory, John Milsted of the Atomic Energy Research Establishment in England and Hugo Atterling, Wilhelm Forsling, Lennart Holm and Björn Aström of the Nobel Institute.

Seven Mills

In its nuclear power plant at Calder Hall, Great Britain is now producing electricity at a cost no higher than that from coal in England, according to a report it has made to the United Nations. The British spokesmen said the cost is seven mills per kilowatt hour.

The UN circulated a questionnaire to its members asking for information on their nuclear power programs. The U. S. Atomic Energy Commission replied that its present generation of experimental power reactors will produce electricity at five to 10 times the costs from conventional fuels, and following this it does not expect nuclear power will begin to be competitive with power from coal or oil until about 1965. But in the U. S. these fuels are considerably less expensive than in Britain.

U. S. Senator Henry M. Jackson last month expressed sharp dissatisfaction with the pace of the U. S. effort. He told a conference of the American Public Power Association: "Almost every one of the reactors we are building is behind schedule. Costs have far exceeded estimates. Safety problems remain unsolved. We must now admit that the road to economic power from the atom is long, rocky and costly."

Accident Epidemiology

Automobile accidents in the U. S. are now the subject of a large-scale investigation as if they were an epidemic—as they are. The Department of the Army, the American Medical Association and other major groups are studying many phases of the matter, from the design of tollbooths to the personality of truck drivers. Ross A. McFarland and Roland C. Moore of the Harvard School of Public Health recently summarized the results so far in *The New England Journal of Medicine*.

At the present rate, traffic accidents will kill or injure one of every 10 persons in the U. S. during the next 15 years.

McFarland and Moore were most impressed with the general finding that "a man drives as he lives." People who are misfits in society, as indicated by contacts with law courts, credit bureaus or social service agencies, are more likely to have repeated accidents than others. A Canadian team studying taxi drivers noted a definite personality type among accident-repeaters—"egocentric, exhibitionistic, resentful of authority, impulsive and lacking in social responsibility." Other research groups discovered specific attitudes which they believe contribute to highway risks. For instance, there is the driver who usually expects that the other fellow will take the action necessary to prevent an accident. There is the one who generally assumes that the road is clear around the curve or over the hill. There is the driver who overestimates his driving ability because he has escaped accident for a long time.

Among other significant findings are that sedatives and tranquilizing drugs dull a driver's skill, and that the dangerous effects of an evening of drinking may last as long as 18 hours, regardless of coffee therapy.

McFarland and Moore found that buses and other vehicles were ill-designed for driving efficiency and safety. They proposed further research on drivers' characteristics and on how the design of vehicles and highways might be adjusted to drivers' limitations.

Chemistry of Mutation

A major advance has been made in the attempt to uncover the chemical basis of heredity. V. M. Ingram of the

SILICONE NEWS

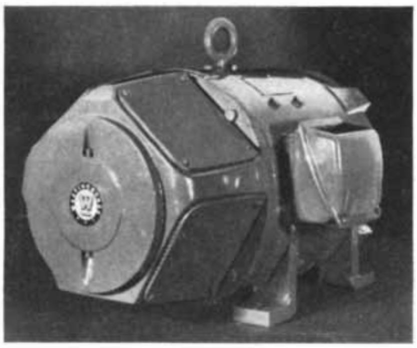
DOW CORNING

New Spice for Sales Recipes

- Silicones up life-expectancy of motor insulation
- More churn astern with Silicone-protected outboard
- Silicones get a "well done" from oven buyers

HOT COMPETITIVE CLIMATE — In today's increasingly competitive markets, many manufacturers are calling on Dow Corning Silicones to supply an extra product value. Here are several new examples of how alert marketers are using silicones to improve performance.

MOTOR MAKES BIG NEWS — A new line of standard dc motors, the Life-Line "H" series, has just been announced by Westinghouse Electric. The insulation in these motors has 10 times the life of insulation in other motors in their class. The new motors provide much faster acceleration and reversal, and promise big reductions in maintenance!



How does Westinghouse achieve these advantages? A silicone insulating system that provides the motors with greater reliability. Although rated at standard temperature rises, Silicones withstand high ambient temperatures and moisture . . . motor trouble due to insulation breakdown is practically eliminated.

Dow Corning silicone insulation plus a highly efficient design make the new Westinghouse motor ideal for automated processes. Here, where the failure of a single motor can shut down whole assembly lines, Life-Line "H" performance will keep production humming. It's calculated to keep Westinghouse sales humming, too.

LITTLE PLUG HELPS MAKE SALE Frequently, in large appliances, a single "plus" feature will sell brand "A" over brand "B". Just such a plus for kitchen ovens is a new plug-in meat thermometer made by King-Seeley Corporation of Ann Arbor, Michigan. A real help to the housewife, it translates meat heat into electrical impulses, so she reads on a dial how well her roast is done.

Silastic*, the Dow Corning Silicone rubber, plays an important part in making this handy unit possible. Silastic resists prolonged heat up to 500 F . . . a temperature that ruins regular rubber. That's why the flexible lead wire is covered with Silastic, and the sealing washers are fabricated from it.

First offered by Philco, this clever and durable thermometer is now a feature of Hotpoint, Magic Chef, Cribben & Saxton, and other ranges. Another example of how silicones help sell!

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

SMOOTH PUTT — The outboard motors that used to be "putt-putts" have grown up into powerful engines. The newest and strongest production outboard carries a whopping 60 hp rating . . . enough to drive a small car! This motor, the "Mark 75", is produced by Kiekhaefer Corporation, makers of the Mercury line.

To help keep the Mark 75 and the eleven other Mercury models running smoothly —come cold, hot, or wet weather— Kiekhaefer employs Dow Corning Silicones. Several rubber, metal, and ceramic parts within the motors are coated with a water repellent silicone compound. The silicone coating preserves, protects, lubricates, and helps prevent short circuits. Here's a case where Dow Corning Silicones assure a steady purr from both motor and satisfied customer.

BABY BILLBOARDS — A slick trick for keeping your company name where it will be seen: give-away packets of Sight Savers imprinted with your sales message.

Sight Savers—the Dow Corning silicone treated tissues for cleaning eyeglasses—are purchased and used regularly by millions of adults. Over 70% of your customers and prospects wear glasses, and glasses need cleaning often. What more logical place to put your message than where it will be repeatedly seen and appreciated? Imprinted Sight Savers are available in any quantity, at a surprisingly low price.

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University of Cambridge has for the first time pinpointed the effect of a single genetic mutation on the molecular structure of a body material.

The mutation is the one that causes sickle cell anemia—a condition characterized by an abnormality in the protein of hemoglobin. Ingram has traced the abnormality to a change in one amino acid out of nearly 300 that make up the protein. He split hemoglobin with an enzyme and separated the resulting mixture of fragments, called peptides, by the processes of paper electrophoresis and chromatography. The peptides then formed a two-dimensional pattern, or "fingerprint," for both normal and sickle cell protein. The normal and sickle cell fingerprints were identical except for one peptide, which is neutral in normal hemoglobin and positively charged in the sickle cell material. This peptide was then analyzed into its constituent amino acids. It proved to consist of a string of nine amino acids which were the same except that one glutamic acid in the normal sample had been replaced by valine in the sickle cell sample.

Big Molecules

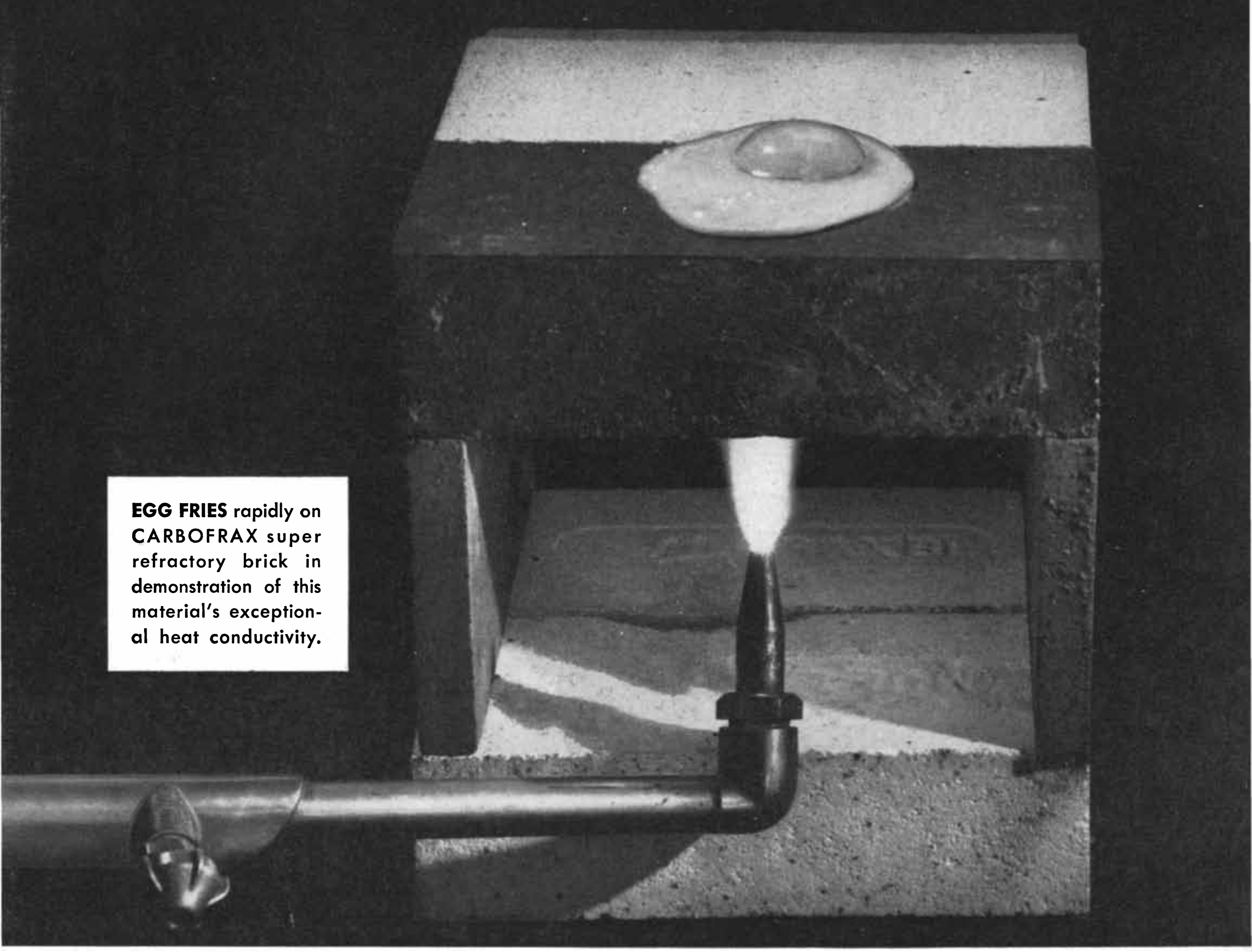
Cellulose, the giant molecule which is the major structural material of the plant world, has been manufactured in the test tube for the first time. Glenn A. Greathouse of the University of Florida performed the feat.

Chemists have long known that cellulose is a chain of glucose molecules, but they have been unable to hook glucose links into such a chain. Greathouse made the hookup with a solution extracted from a cellulose-building bacterium, *Acetobacter xylinum*. The extract, which contains no intact cells or cellulose, is prepared by breaking open the bacteria and filtering their contents. When glucose and the energy-rich compound known as ATP are added, cellulose appears in the solution.

Liquid Electronics

A new type of electric-circuit element which performs many of the functions of vacuum tubes or transistors and a few tricks of its own has been developed by the Naval Ordnance Laboratory. It operates with ions in a solution, whence its name, "solion."

The basic solion device consists of a pair of electrodes immersed in a solution containing iodine ions. When a voltage is applied to the electrodes, iodine ions take electrons from the cathode (negative electrode) and deliver



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electrons to the anode. Thus the cell conducts a current only for an instant, until all iodine ions near the electrodes are used up. But if the cell is subjected to an outside force, such as from a sound wave or an acceleration, the liquid is stirred up and new ions are provided at the electrodes. Now a current flows again, and its size is determined by the amount of the applied force. Hence the solion can be used to measure sound energy or to detect changes in motion, as in an inertial navigation system. It is also an amplifier: its output of electrical energy can be thousands of times greater than the energy of the input force. However, the solion is limited to a small range of frequencies: up to a few hundred cycles per second.

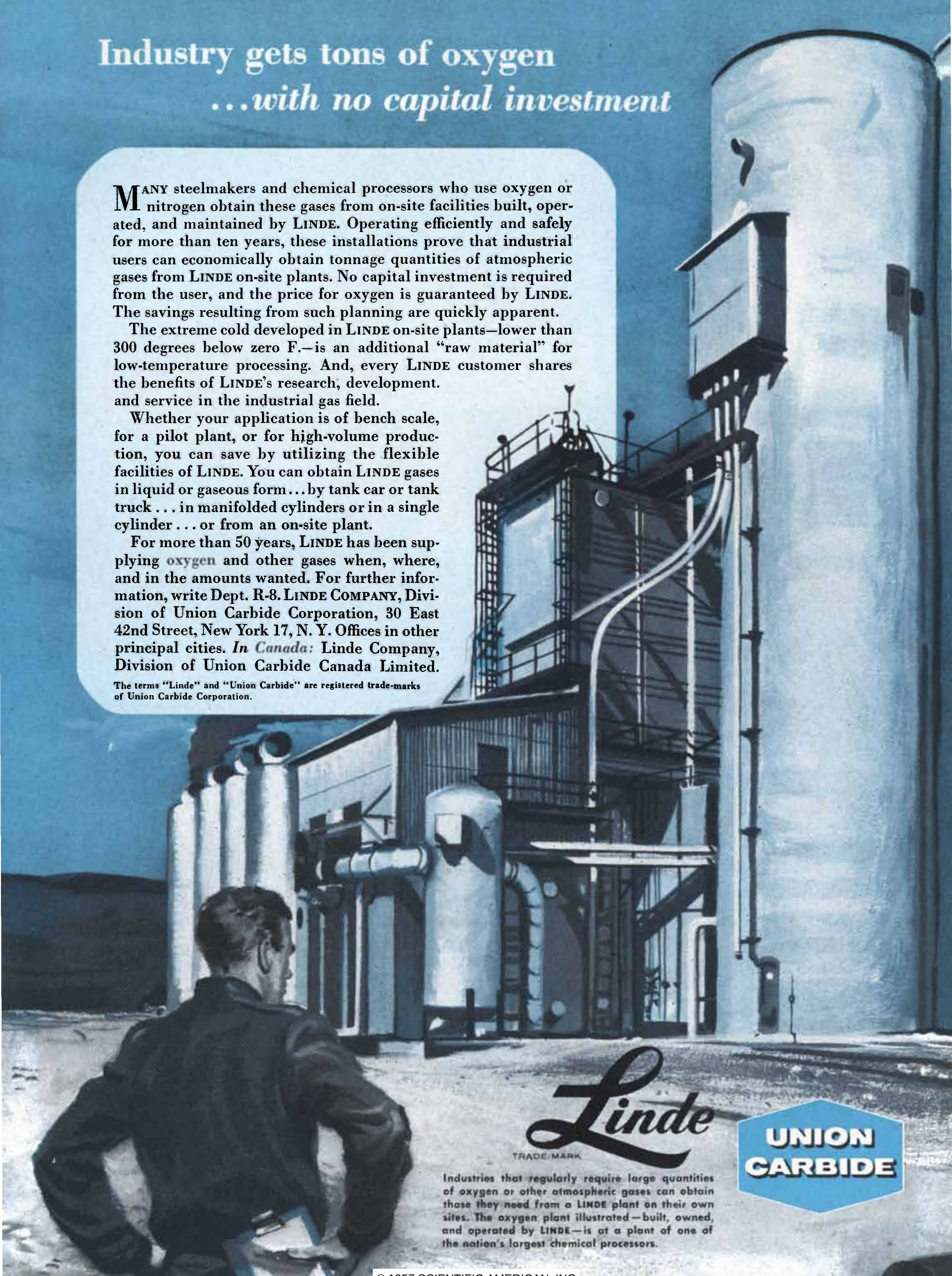
Refractory Metals Yield

Researchers at the National Bureau of Standards have succeeded for the first time in electroplating metals with beryllium and alloys of magnesium, titanium and zirconium—the important family of light, strong metals that are highly resistant to heat and corrosion. These metals cannot be deposited from a water solution: they replace hydrogen and thus simply cause the water to dissociate when a current is passed through the solution. The NBS group was able to deposit them from a bath of molten salts, but obtained the metals only as powder or flakes. Finally they found a series of organic solvents which form loose combinations with various refractory metal salts. When current is passed through these solutions the metals plate out in smooth, adhesive surfaces. Some of the solvents are explosively inflammable, and the electrolysis must be conducted in an atmosphere of inert gas. The process is not yet commercially practical, but the Bureau group believes it soon will be.

Of Tranquil Mice and Men

The tranquilizing drugs are definitely what is needed for crowded living. Two workers have just proved it beyond peradventure—at least for mice.

Louis Lasagna and William P. McCann of the Johns Hopkins Medical School cooped up groups of mice in canisters and gave half the groups Miltown, the other half nothing. Half an hour later they injected all the groups with a lethal dose of amphetamine. At the end of the experiment the untranquilized mice were all dead and the tranquilized ones were not even breathing hard.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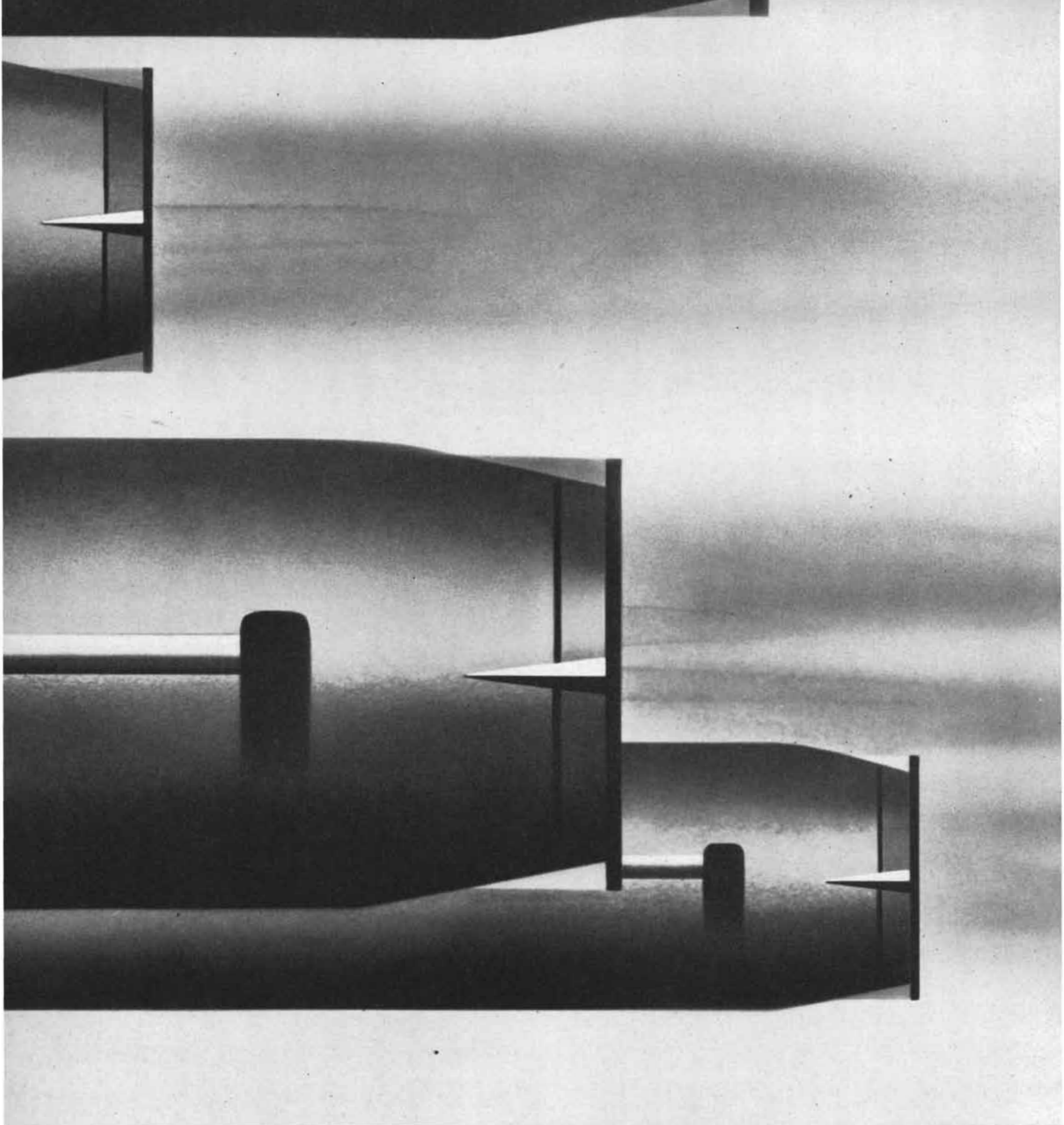

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THE EAR

It translates sound between some 16 cycles per second and 20,000 into nerve impulses. Together with the auditory centers of the brain, it is an instrument that is not only remarkably sensitive but also selective

by Georg von Békésy

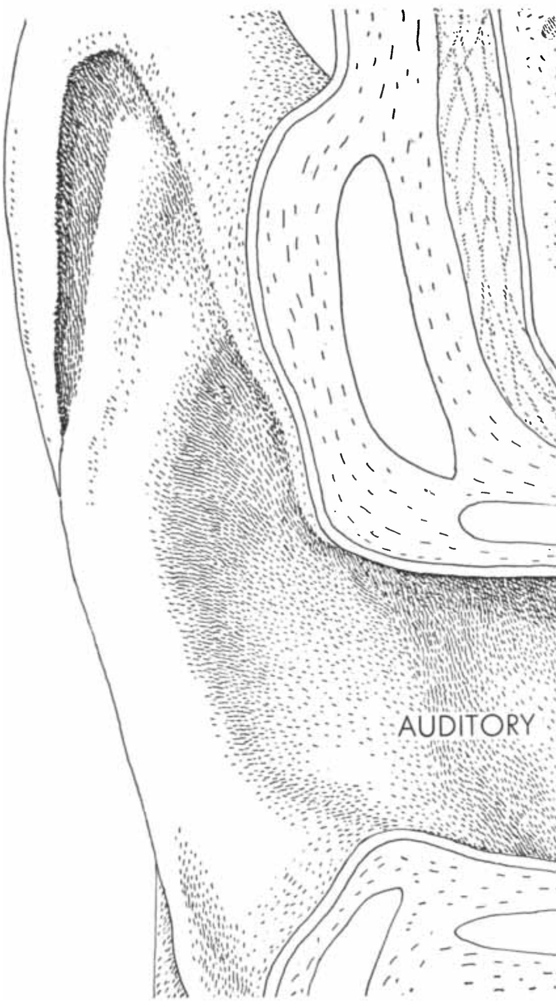
Even in our era of technological wonders, the performances of our most amazing machines are still put in the shade by the sense organs of the human body. Consider the accomplishments of the ear. It is so sensitive that it can almost hear the random rain of air molecules bouncing against the eardrum. Yet in spite of its extraordinary sensitivity the ear can withstand the pounding of sound waves strong enough to set the body vibrating. The ear is equipped, moreover, with a truly impressive selectivity. In a room crowded with people talking, it can suppress most of the noise and concentrate on one speaker. From the blended sounds of a symphony orchestra the ear of the conductor can single out the one instrument that is not performing to his satisfaction.

In structure and in operation the ear is extraordinarily delicate. One measure of its fineness is the tiny vibrations to which it will respond. At some sound frequencies the vibrations of the eardrum are as small as one billionth of a centimeter—about one tenth the diameter of the hydrogen atom! And the vibrations of the very fine membrane in the inner ear which transmits this stimulation to the auditory nerve are nearly 100 times smaller in amplitude. This fact alone is enough to explain why hearing has so long been one of the mysteries of physiology. Even today we do not know how these minute vibrations stimulate the nerve endings. But thanks to refined electro-acoustical instruments we do know quite a bit now about how the ear functions.

What are the ear's abilities? We can get a quick picture of the working condition of an ear by taking an audiogram, which is a measure of the threshold of hearing at the various sound frequencies. The hearing is tested with pure tones at various frequencies, and the audiogram tells how much sound pressure on the eardrum (*i.e.*, what intensity of sound) is necessary for the sound at each frequency to be just barely audible. Curiously, the audiogram curve often is very much the same for the various members of a family; possibly this is connected in some way with the similarity in the shape of the face.

The ear is least sensitive at the low frequencies: for instance, its sensitivity for a tone of 100 cycles per second is 1,000 times lower than for one at 1,000 cycles per second. This comparative insensitivity to the slower vibrations is an obvious physical necessity, because otherwise we would hear all the vibrations of our own bodies. If you stick a finger in each ear, closing it to air-borne sounds, you hear a very low, irregular tone, produced by the contractions of the muscles of the arm and finger. It is interesting that the ear is just insensitive enough to low frequencies to avoid the disturbing effect of the noises produced by muscles, bodily movements, etc. If it were any more sensitive to these frequencies than it is, we would even hear the vibrations of the head that are produced by the shock of every step we take when walking.

On the high-frequency side the range that the ear covers is remarkable. In childhood some of us can hear well at frequencies as high as 40,000 cycles per second. But with age our acuteness of hearing in the high-frequency range steadily falls. Normally the drop is almost as regular as clockwork: testing several persons in their 40s with tones at a fixed level of intensity, we found that over a period of five years their upper limit dropped about 80 cycles per second every six months. (The experiment was quite depressing to most of the participants.) The aging of the ear is not difficult to understand if we assume that the elasticity of the tissues in the inner ear declines in the same way as that of the skin: it is well known that the skin becomes less resilient as we grow old—a



PARTS OF THE EAR are illustrated in somewhat simplified cross section. Be-

phenomenon anyone can test by lifting the skin on the back of his hand and measuring the time it takes to fall back.

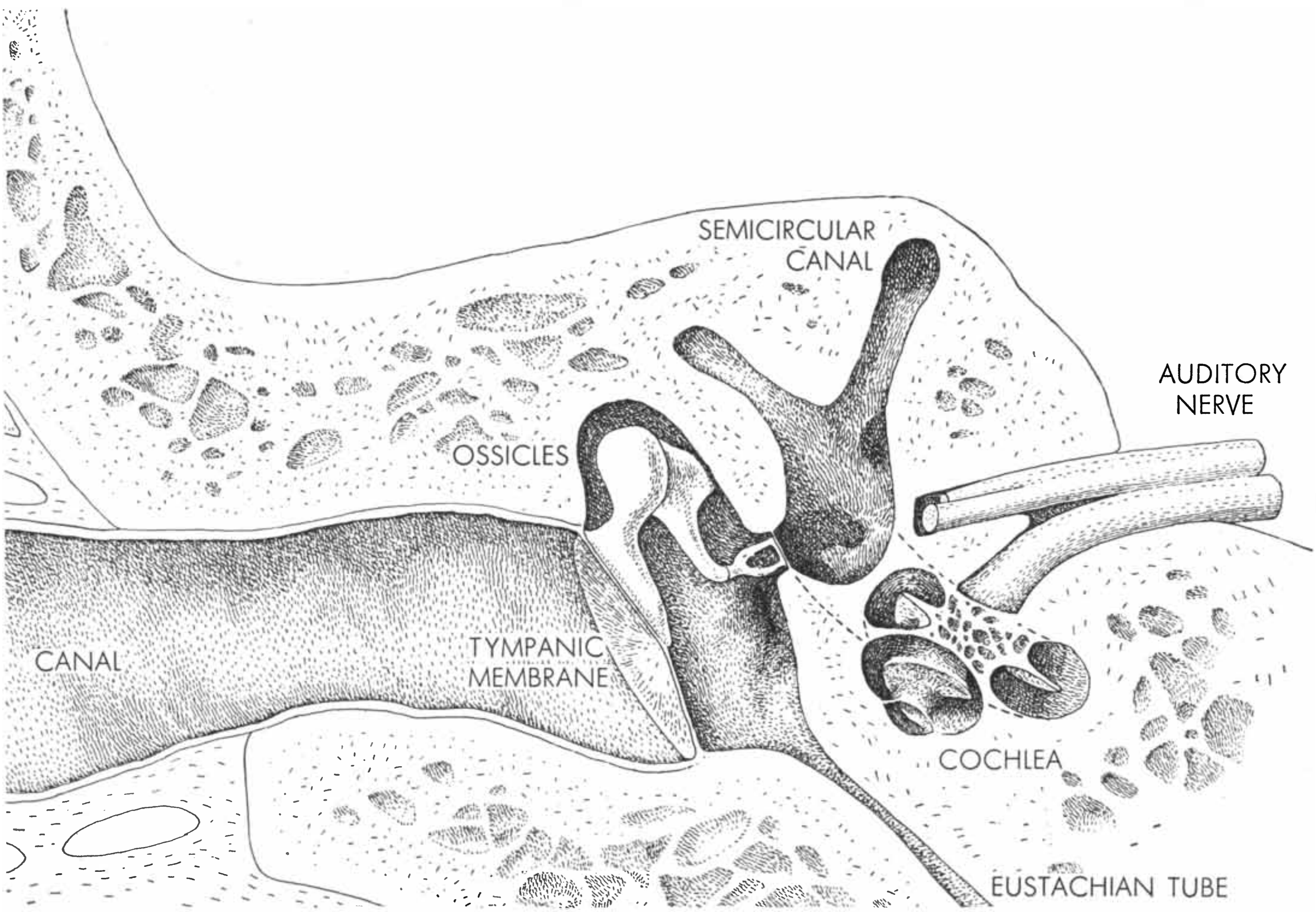
However, the loss of hearing sensitivity with age may also be due to nerve deterioration. Damage to the auditory nervous system by extremely loud noises, by drugs or by inflammation of the inner ear can impair hearing. Sometimes after such damage the hearing improves with time; sometimes (*e.g.*, when the damaging agent is streptomycin) the loss is permanent. Unfortunately a physician cannot predict the prospects for recovery of hearing loss, because they vary from person to person.

Psychological factors seem to be involved. Occasionally, especially after an ear operation, a patient appears to improve in hearing only to relapse after a short time. Some reports have even suggested that operating on one ear has improved the unoperated ear as well. Since such an interaction between the two ears would be of considerable neurological interest, I have investigated the matter, but I have never found an improvement in the untreated ear that could be validated by an objective test.

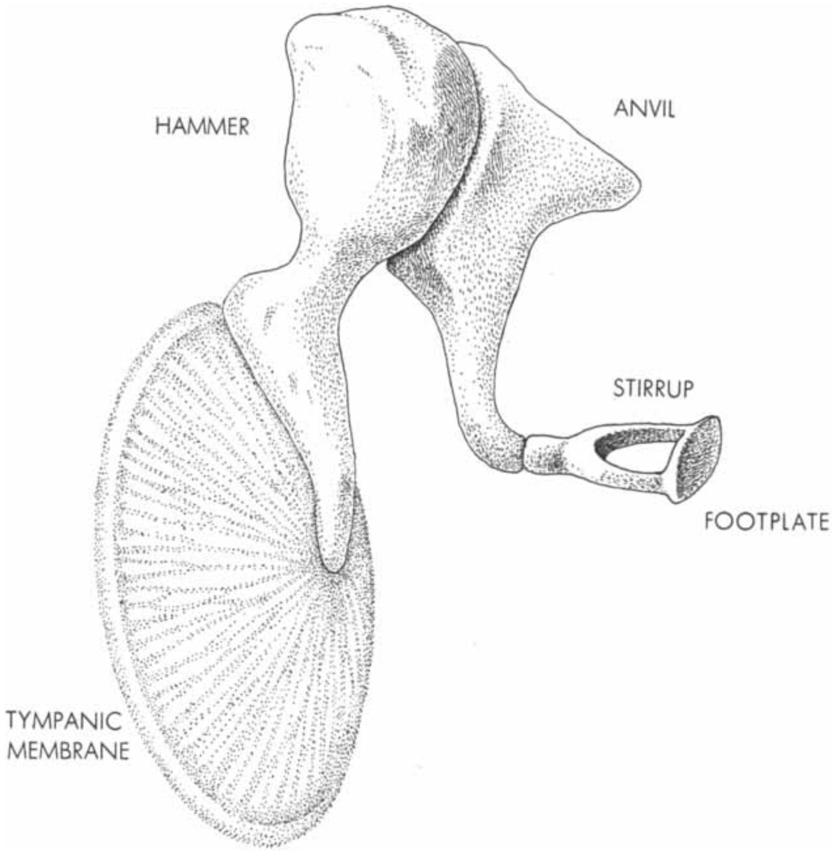
Structure of the Ear

To understand how the ear achieves its sensitivity, we must take a look at the anatomy of the middle and the inner ear. When sound waves start the eardrum (tympanic membrane) vibrating, the vibrations are transmitted via certain small bones (ossicles) to the fluid of the inner ear. One of the ossicles, the tiny stirrup (weighing only about 1.2 milligrams), acts on the fluid like a piston, driving it back and forth in the rhythm of the sound pressure. These movements of the fluid force into vibration a thin membrane, called the basilar membrane. The latter in turn finally transmits the stimulus to the organ of Corti, a complex structure which contains the endings of the auditory nerves. The question immediately comes up: Why is this long and complicated chain of transmission necessary?

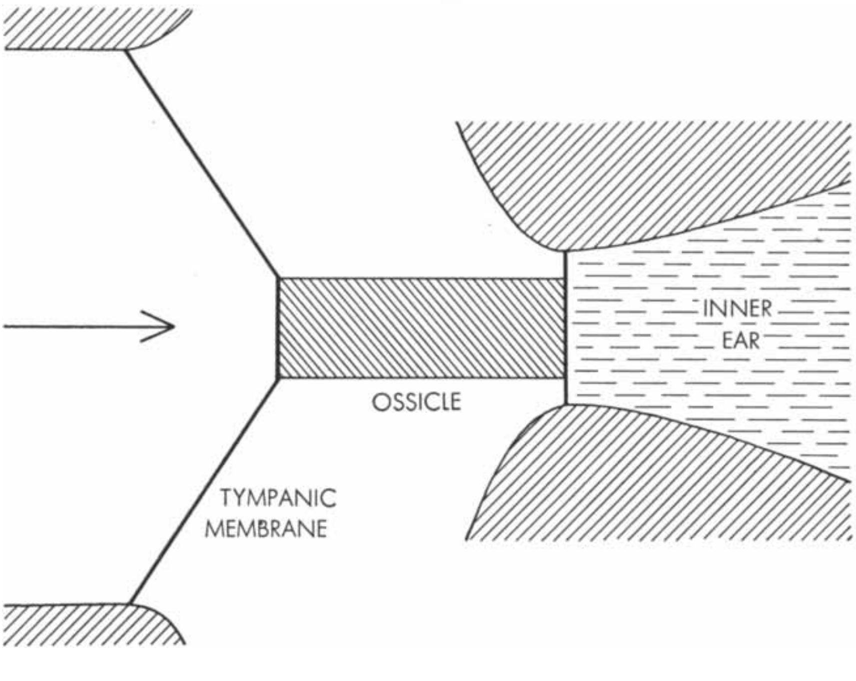
The reason is that we have a formidable mechanical problem if we are to extract the utmost energy from the sound waves striking the eardrum. Usually when a sound hits a solid surface, most of its energy is reflected away. The problem the ear has to solve is to absorb this energy. To do so it has to act as a kind of mechanical transformer, converting the large amplitude of the sound pressure waves in the air into more forceful vibrations of smaller amplitude. A hydraulic press is such a transformer: it multiplies the pressure acting on the surface of a piston by concentrating the force of the pressure upon a second piston of smaller area. The middle ear acts exactly like a hydraulic press: the tiny footplate of the stirrup transforms the small pressure on the surface of the eardrum into a 22-fold greater pressure on the fluid of the inner ear. In this way the



tween the eardrum (tympanic membrane) and the fluid-filled inner ear are the three small bones (ossicles) of the middle ear. The auditory nerve endings are in an organ (*not shown*) between the plate of bone which spirals up the cochlea and the outer wall of the cochlea.



THREE OSSICLES transmit the vibrations of the tympanic membrane to the inner ear. The footplate of stirrup, surrounded by a narrow membrane, presses against inner-ear fluid.



HOW OSSICLES ACT as a piston pressing against the fluid of the inner ear is indicated by this drawing. Pressure of the vibrations of tympanic membrane are amplified 22 times.

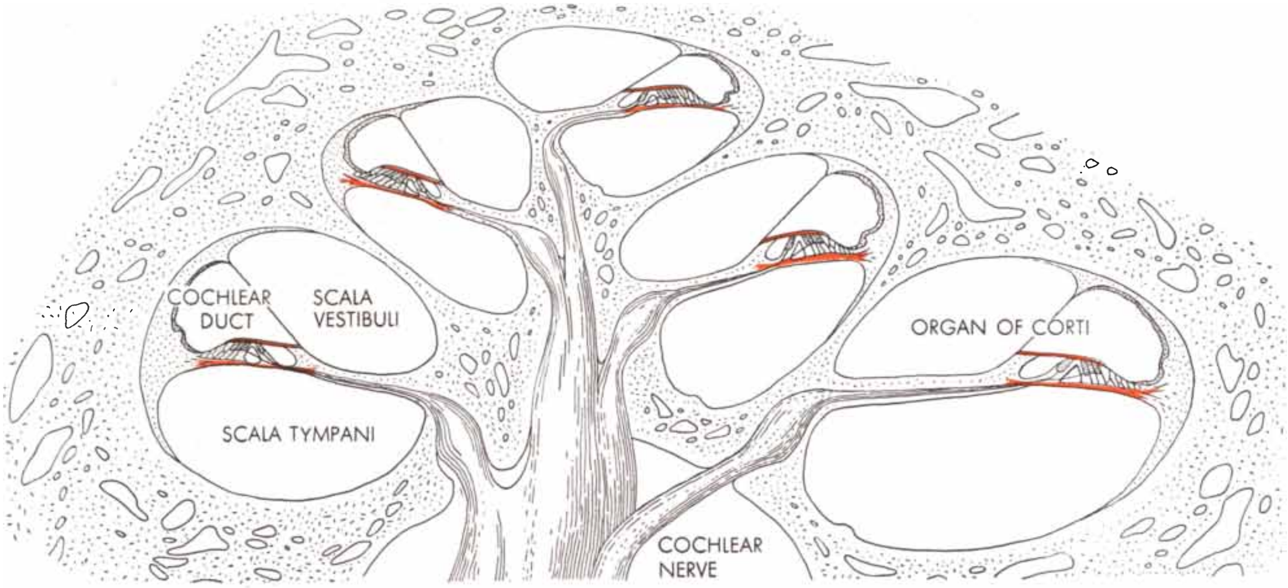
ear absorbs the greater part of the sound energy and transmits it to the inner ear without much loss.

But it needs another transformer to amplify the pressure of the fluid into a still larger force upon the tissues to which the nerves are attached. I think the ear's mechanism for this purpose is very ingenious indeed. It is based on the fact that a flat membrane, stretched to cover the opening of a tube, has a lateral tension along its surface. This tension can be increased tremendously if pressure is applied to one side of the membrane. And that is the function of the organ of Corti. It is constructed in such a way that pressure on the basilar membrane is transformed into shearing forces many times larger on the other side of the organ [*see diagram at bottom of opposite page*]. The enhanced shearing forces rub upon extremely sensitive cells attached to the nerve endings.

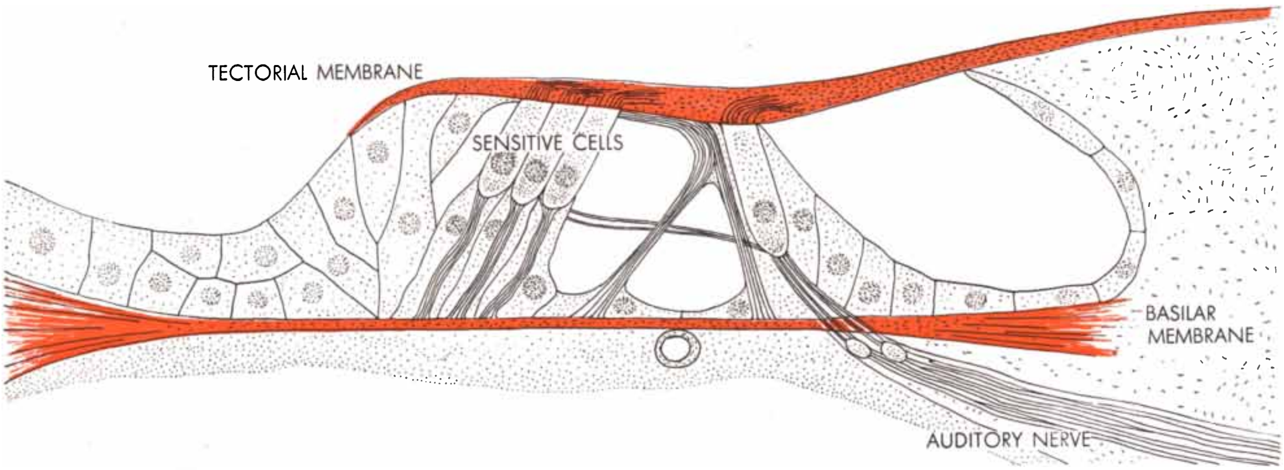
The eardrum is not by any means the only avenue through which we hear. We also hear through our skull, which is to say, by bone conduction. When we click our teeth or chew a cracker, the sounds come mainly by way of vibrations of the skull. Some of the vibrations are transmitted directly to the inner ear, by-passing the middle ear. This fact helps in the diagnosis of hearing difficulties. If a person can hear bone-conducted sounds but is comparatively deaf to air-borne sounds, we know that the trouble lies in the middle ear. But if he hears no sound by bone conduction, then his auditory nerves are gone, and there is no cure for his deafness. This is an old test, long used by deaf musicians. If a violin player cannot hear his violin even when he touches his teeth to the vibrating instrument, then he knows he suffers from nerve deafness, and there is no cure.

Speaking and Hearing

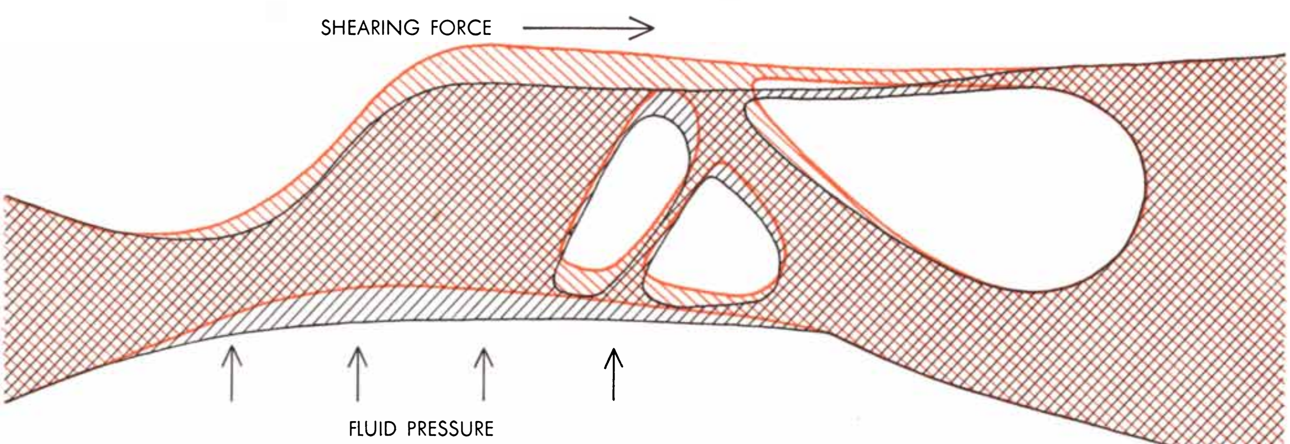
Hearing by bone conduction plays an important role in the process of speaking. The vibrations of our vocal cords not only produce sounds which go to our ears via the air but also cause the body to vibrate, and the vibration of the jawbone is transmitted to the ear canal. When you hum with closed lips, the sounds you hear are to a large degree heard by bone conduction. (If you stop your ears with your fingers, the hum sounds much louder.) During speaking and singing, therefore, you hear two different sounds—one by bone conduction and the other by air conduction. Of course another listener hears only the air-conducted sounds. In these sounds



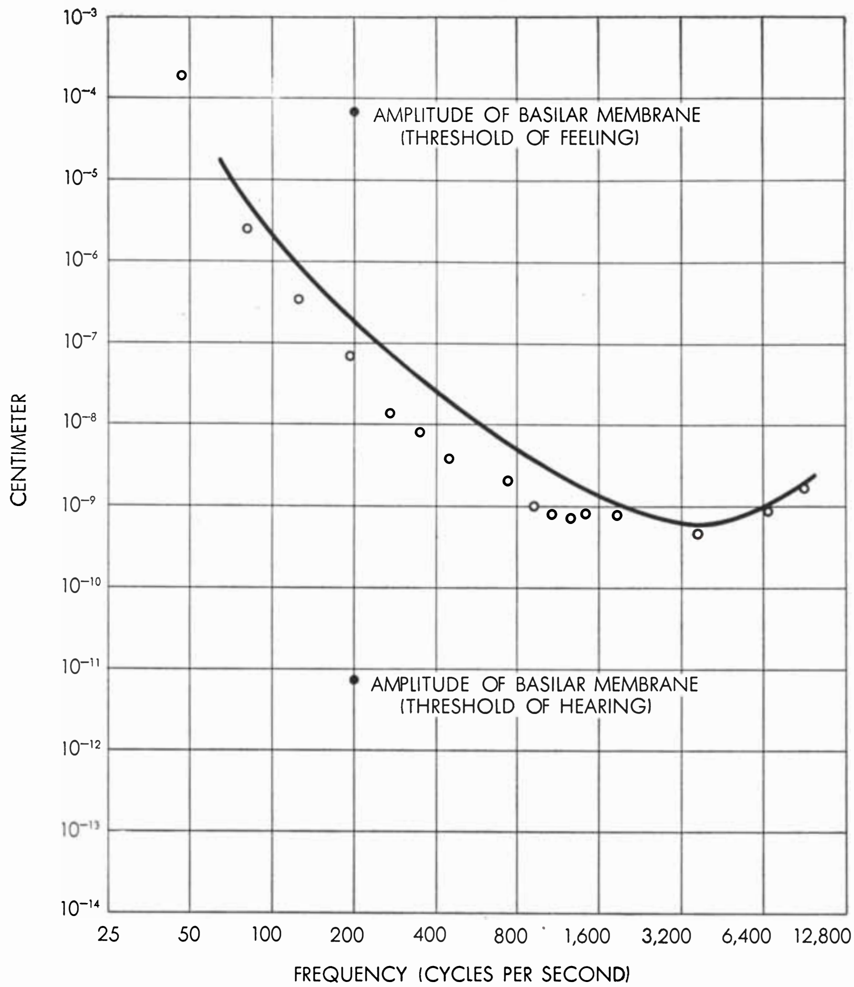
TUBE OF THE COCHLEA, coiled like the shell of a snail, is depicted in cross section. The plate of bone which appears in the cross section on pages 66 and 67 juts from the inside of the tube. Between it and the outside of the tube is the sensitive organ of Corti.



ORGAN OF CORTI lies between the basilar and tectorial membranes. Within it are sensitive cells which are attached to a branch of the auditory nerve (*lower right*). When fluid in scala tympani (*see drawing at top of page*) vibrates, these cells are stimulated.



HOW VIBRATION FORCES ARE AMPLIFIED by the organ of Corti is indicated by this drawing. When the vibration of the fluid in the scala tympani exerts a force on the basilar membrane, a larger shearing force is brought to bear on tectorial membrane.



SENSITIVITY OF THE EAR is indicated by this curve, in which the amplitude of the vibrations of the tympanic membrane in fractions of a centimeter is plotted against the frequency of sound impinging on the membrane. Diameter of hydrogen atom is 10^{-8} centimeter.

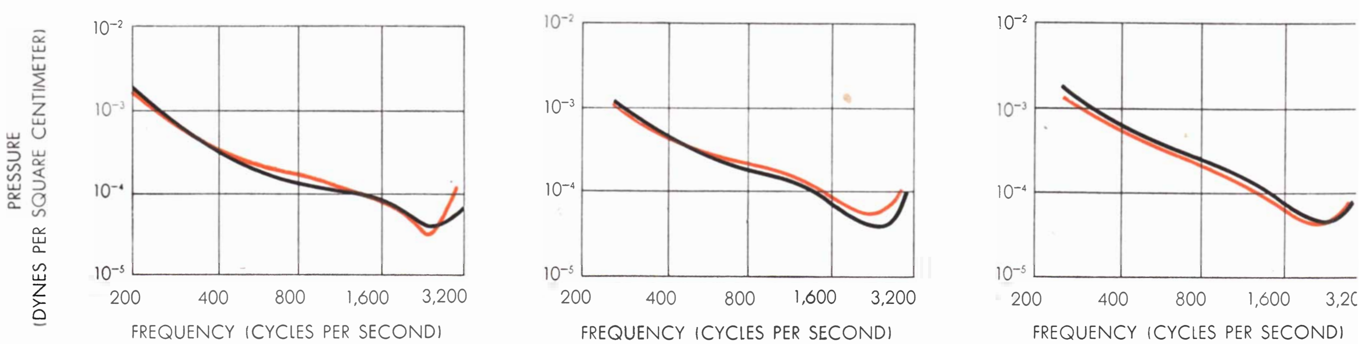
some of the low-frequency components of the vocal cords' vibrations are lost. This explains why one can hardly recognize his own voice when he listens to a recording of his speech. As we normally hear ourselves, the low-frequency vibrations of our vocal cords, conducted to our own ears by the bones, make our speech sound much more powerful and dynamic than the pure sound waves heard by a second person or through a recording system. Consequently the recording of our voice may strike us as very thin and disappointing. From this point of view we have to admire the astonishing performance of an opera singer. The singer and the audience hear rather different sounds, and it is a miracle to me that they understand each other so well. Perhaps young singers would progress faster if during their training they spent more time studying recordings of their voices.

Feedback to the Voice

The control of speaking and singing involves a complicated feedback system. Just as feedback between the eyes and the muscles guides the hand when it moves to pick up an object, so feedback continually adjusts and corrects the voice as we speak or sing. When we start to sing, the beginning of the sound tells us the pitch, and we immediately adjust the tension of the vocal cords if the pitch is wrong. This feedback requires an exceedingly elaborate and rapid mechanism. How it works is not yet entirely understood. But it is small wonder that it takes a child years to learn to speak, or that it is almost impossible for an adult to learn to speak a foreign language with the native accents.

Any disturbance in the feedback immediately disturbs the speech. For instance, if, while a person is speaking, his speech is fed back to him with a time delay by means of a microphone and receivers at his ears, his pronunciation and accent will change, and if the delay interval is made long enough, he will find it impossible to speak at all. This phenomenon affords an easy test for exposing pretended deafness. If the subject can continue speaking normally in the face of a delayed feedback through the machine to his ears, we can be sure that he is really deaf.

The same technique can be used to assess the skill of a pianist. A piano player generally adjusts his touch to the acoustics of the room: if the room is very reverberant, so that the music sounds



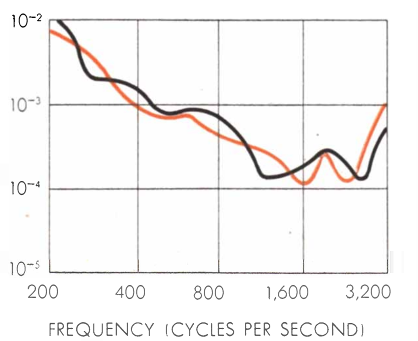
AUDIOGRAMS plot the threshold of hearing (in terms of pressure on the tympanic membrane) against the frequency of sound. The first three audiograms show the threshold for three members of the same family; the fourth, the threshold for an unrelated person. The black curves represent the threshold for one ear of the subject; the colored curves, for the other ear of the same subject. The curves in-

too loud, he uses a lighter touch; if the sound is damped by the walls, he strengthens his touch. We had a number of pianists play in a room where the damping could be varied, and recorded the amplitude of the vibrations of the piano's sounding board while the musicians played various pieces. When they played an easy piece, their adjustment to the acoustics was very clear: as the sound absorption of the room was increased, the pianist played more loudly, and when the damping on the walls was taken away, the pianist's touch became lighter. But when the piece was difficult, many of the pianists concentrated so hard on the problems of the music that they failed to adjust to the feedback of the room. A master musician, however, was not lost to the sound effects. Taking the technical difficulties of the music in stride, he was able to adjust the sound level to the damping of the room with the same accuracy as for an easy piece. Our rating of the pianists by this test closely matched their reputation among musical experts.

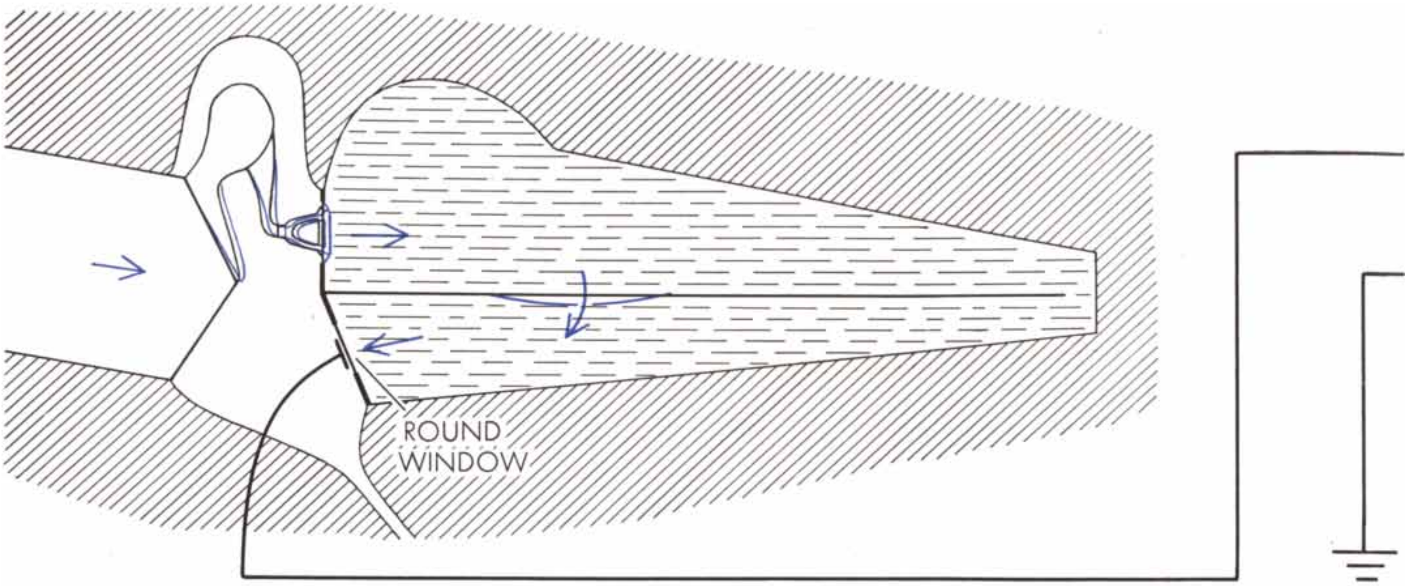
Suppressed Sounds

In connection with room acoustics, I should like to mention one of the ear's most amazing performances. How is it that we can locate a speaker, even without seeing him, in a bare-walled room where reflections of his voice come at us from every side? This is an almost unbelievable performance by the ear. It is as if, looking into a room completely lined with mirrors, we saw only the real figure and none of the hundreds of reflected images. The eye cannot suppress the reflections, but the ear can. The ear is able to ignore all the sounds except the first that strikes it. It has a built-in inhibitory mechanism.

One of the most important factors that subordinate the reflected sounds is the



dicate that in normal hearing the threshold in both ears, and the threshold in members of the same family, are remarkably similar.



ELECTRICAL POTENTIALS of the microphonic type generated by the inner ear of an experimental animal can be detected by this arrangement. At left is a highly schematic diagram of the ear; the cochlea is represented in cross section by the fluid-filled chamber and the organ of Corti by the horizontal line in this chamber. When the vibrations of the eardrum are transmitted to the organ of Corti,

delay in their arrival; necessarily they come to the ear only after the sound that has traveled directly from the speaker to the listener. The reflected sounds reinforce the loudness and tone volume of the direct sound, and perhaps even modify its localization, but by and large, they are not distinguishable from it. Only when the delay is appreciable does a reflected sound appear as a separate unit—an echo. Echoes often are heard in a large church, where reflections may lag more than half a second behind the direct sound. They are apt to be a problem in a concert hall. Dead walls are not desirable, because the music would sound weak. For every size of concert room there is an optimal compromise on wall reflectivity which will give amplification to the music but prevent disturbing echoes.

In addition to time delay, there are other factors that act to inhibit some sounds and favor others. Strong sounds generally suppress weaker ones. Sounds in which we are interested take precedence over those that concern us less, as I pointed out in the examples of the speaker in a noisy room and the orchestra conductor detecting an errant instrument. This brings us to the intimate collaboration between the ear and the nervous system.

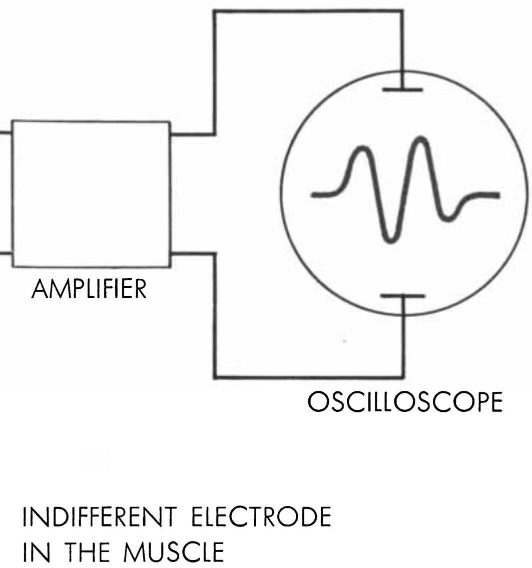
Auditory Messages

Any stimulation of the ear (*e.g.*, any change in pressure) is translated into electrical messages to the brain via the nerves. We can therefore draw information about the ear from an analysis of these electrical impulses, now made possible by electronic instruments. There are two principal types of electric potential that carry the messages. One is a continuous, wavelike potential which has been given the name microphonic. In experimental animals such as guinea pigs and cats the microphonics are large enough to be easily measured (they range up to about half a millivolt). It has turned out that the magnitude of the microphonics produced in the inner ear is directly proportional to the displacements of the stirrup footplate that set the fluid in the inner ear in motion. The microphonics therefore permit us to determine directly to what extent the sound pressure applied to the eardrum is transmitted to the inner ear, and they have become one of the most useful tools for exploring sound transmission in the middle ear. For instance, there used to be endless discussion of the simple question: Just how much does perforation of the eardrum affect hearing? The question has now been answered with mathematical precision by experiments on animals. A hole of precisely measured size is drilled in the eardrum, and the amount of hearing loss is determined by the change in the microphonics. This type of observation on cats has shown that a perforation about one millimeter in diameter destroys hearing at the frequencies below 100 cycles per second but causes almost no impairment of hearing in the range of frequencies above 1,000 cycles per second. From studies of the physical properties of the human ear we can judge that the findings on animals apply fairly closely to man also.

The second type of electric potential takes the form of sharp pulses, which appear as spikes in the recording instrument. The sound of a sharp click produces a series of brief spikes; a pure tone generates volleys of spikes, generally in the rhythm of the period of the tone. We can follow the spikes along the nerve pathways all the way from the inner ear up to the cortex of the brain. And when we do, we find that stimulation of specific spots on the membrane of the inner ear seems to be projected to corresponding spots in the auditory area of the cortex. This is reminiscent of the projection of images on the retina of the eye to the visual area of the brain. But in the case of the ear the situation must be more complex, because there are nerve branches leading to the opposite ear and there seem to be several auditory projection areas on the surface of the brain. At the moment research is going on to find out how the secondary areas function and what their purpose is.

Detecting Pitch

The orderly projection of the sensitive area of the inner ear onto the higher brain levels is probably connected with the resolution of pitch. The ear itself can analyze sounds and separate one tone from another. There are limits to this ability, but if the frequencies of the



its microphonic potentials can be picked up at the round window of the cochlea and displayed on the face of an oscilloscope (*right*).

tones presented are not too close together, they are discriminated pretty well. Long ago this raised the question: How is the ear able to discriminate the pitch of a tone? Many theories have been argued, but only within the last decade has it been possible to plan pertinent experiments.

In the low-frequency range up to 60 cycles per second the vibration of the basilar membrane produces in the auditory nerve volleys of electric spikes synchronous with the rhythm of the sound. As the sound pressure increases, the number of spikes packed into each period increases. Thus two variables are transmitted to the cortex: (1) the number of spikes and (2) their rhythm. These two variables alone convey the loudness and the pitch of the sound.

Above 60 cycles per second a new phenomenon comes in. The basilar membrane now begins to vibrate unequally over its area: each tone produces a maximal vibration in a different area of the membrane. Gradually this selectivity takes over the determination of pitch, for the rhythm of the spikes, which indicates the pitch at low frequencies, becomes irregular at the higher ones. Above 4,000 cycles per second pitch is determined entirely by the location of the maximal vibration amplitude along the basilar membrane. Apparently there is an inhibitory mechanism which suppresses the weaker stimuli and thus sharpens considerably the sensation around the maximum. This type of inhibition can also operate in sense organs such as the skin and the eye. In order to see sharply we need not only a sharp image of the object on the retina but also an inhibitory system to suppress stray light entering the eye. Otherwise we would see the object surrounded by a halo. The ear is much the same. Without inhibitory effects a tone would sound like a noise of a certain pitch but not like a pure tone.

We can sum up by saying that the basilar membrane makes a rough, mechanical frequency analysis, and the auditory nervous system sharpens the analysis in some manner not yet understood. It is a part of the general functioning of the higher nerve centers, and it will be understood only when we know more about the functioning of these centers. If the answer is found for the ear, it will probably apply to the other sense organs as well.

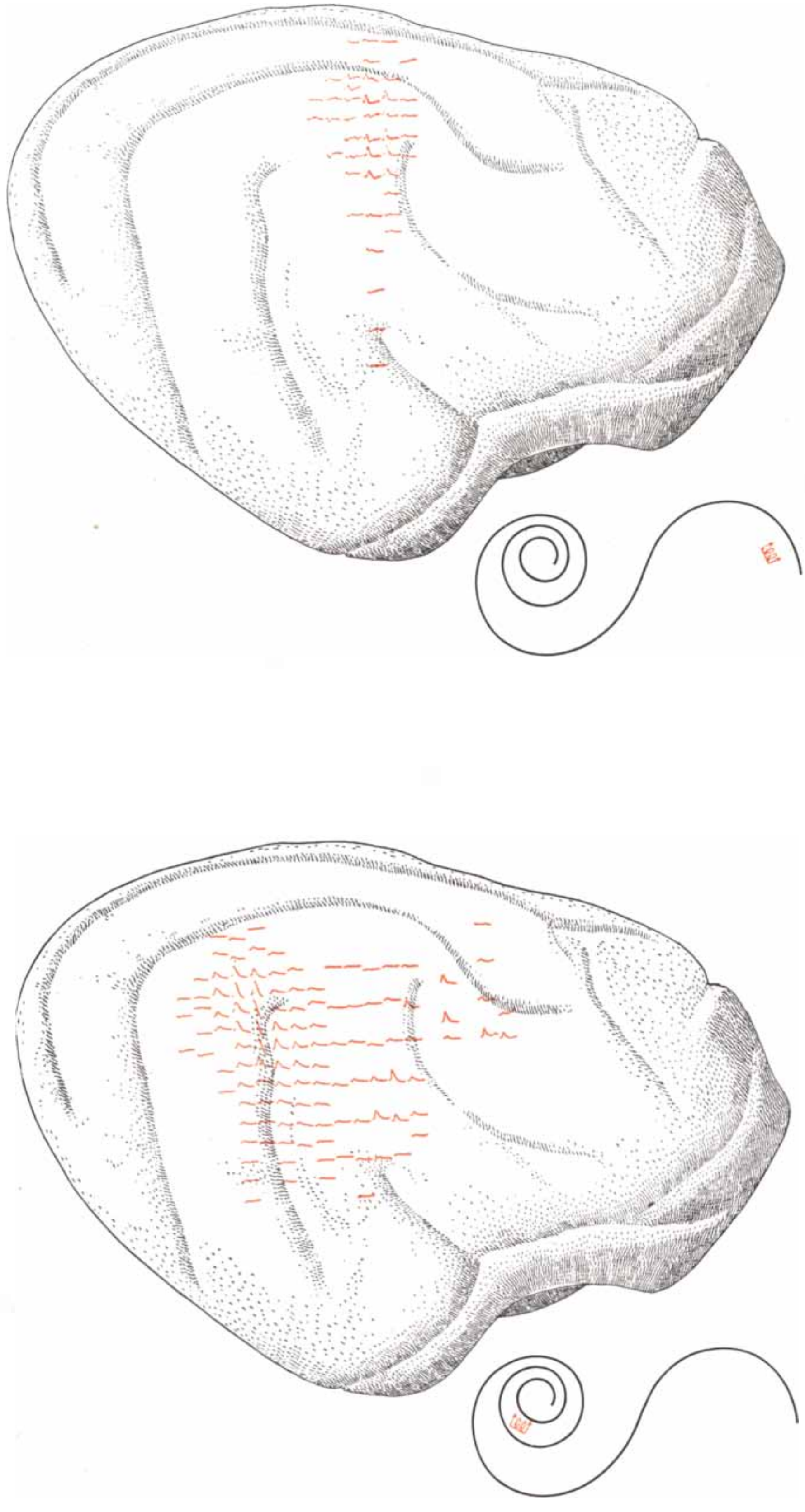
Deafness

Now let us run briefly over some of the types of hearing disorders, which have become much more understandable as a result of recent experimental researches.

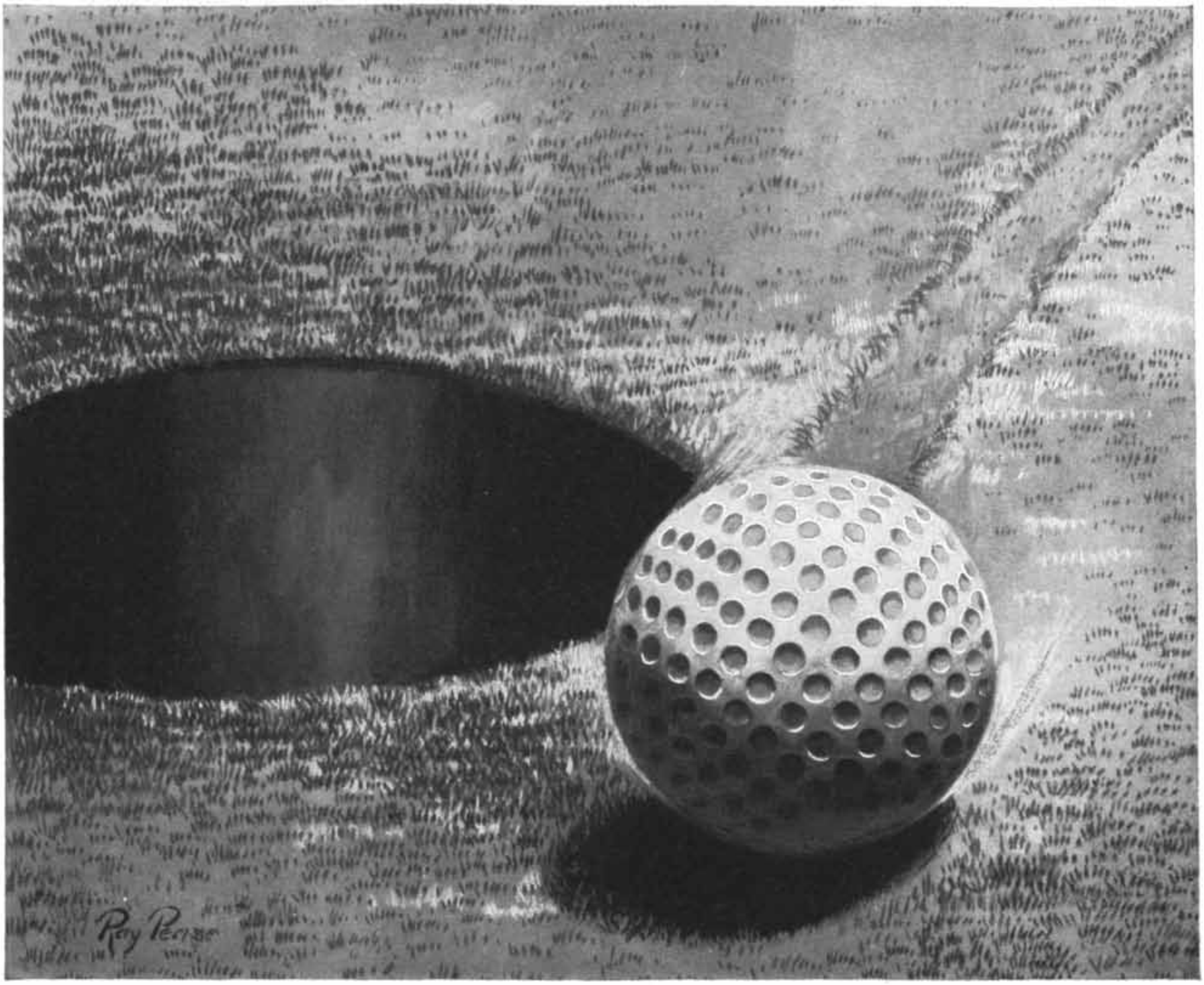
Infections of the ear used to be responsible for the overwhelming majority of the cases of deafness. Ten years ago in a large city hospital there was a death almost every day from such infections. Thanks to antibiotics, they can now be arrested, and, if treated in time, an ear infection is seldom either fatal or destructive of hearing, though occasionally an operation is necessary to scoop out the diseased part of the mastoid bone.

The two other principal types of deafness are those caused by destruction of the auditory nerves and by otosclerosis (a tumorous bone growth). Nerve deafness cannot be cured: no drug or mechanical manipulation or operation can restore the victim's hearing. But the impairment of hearing caused by otosclerosis can usually be repaired, at least in part.

Otosclerosis is an abnormal but painless growth in a temporal bone (*i.e.*, at the side of the skull, near the middle ear). If it does not invade a part of the ear that participates in the transmission of sound, no harm is done to the hearing. But if the growth happens to involve the stirrup footplate, it will reduce or even completely freeze the footplate's ability to make its piston-like movements; the vibrations of the eardrum then can no longer be transmitted to the inner ear. An otosclerotic growth can occur at any age, may slow down for many years, and may suddenly start up again. It is found



NERVE IMPULSES due to the electrical stimulation of the organ of Corti were localized on the surface of the brain of a cat. The spirals below each of these drawings of a cat's brain represent the full length of the organ of Corti. The pairs of colored arrows on each spiral indicate the point at which the organ was stimulated. The colored peaks superimposed on the brains represent the electrical potentials detected by an electrode placed at that point.



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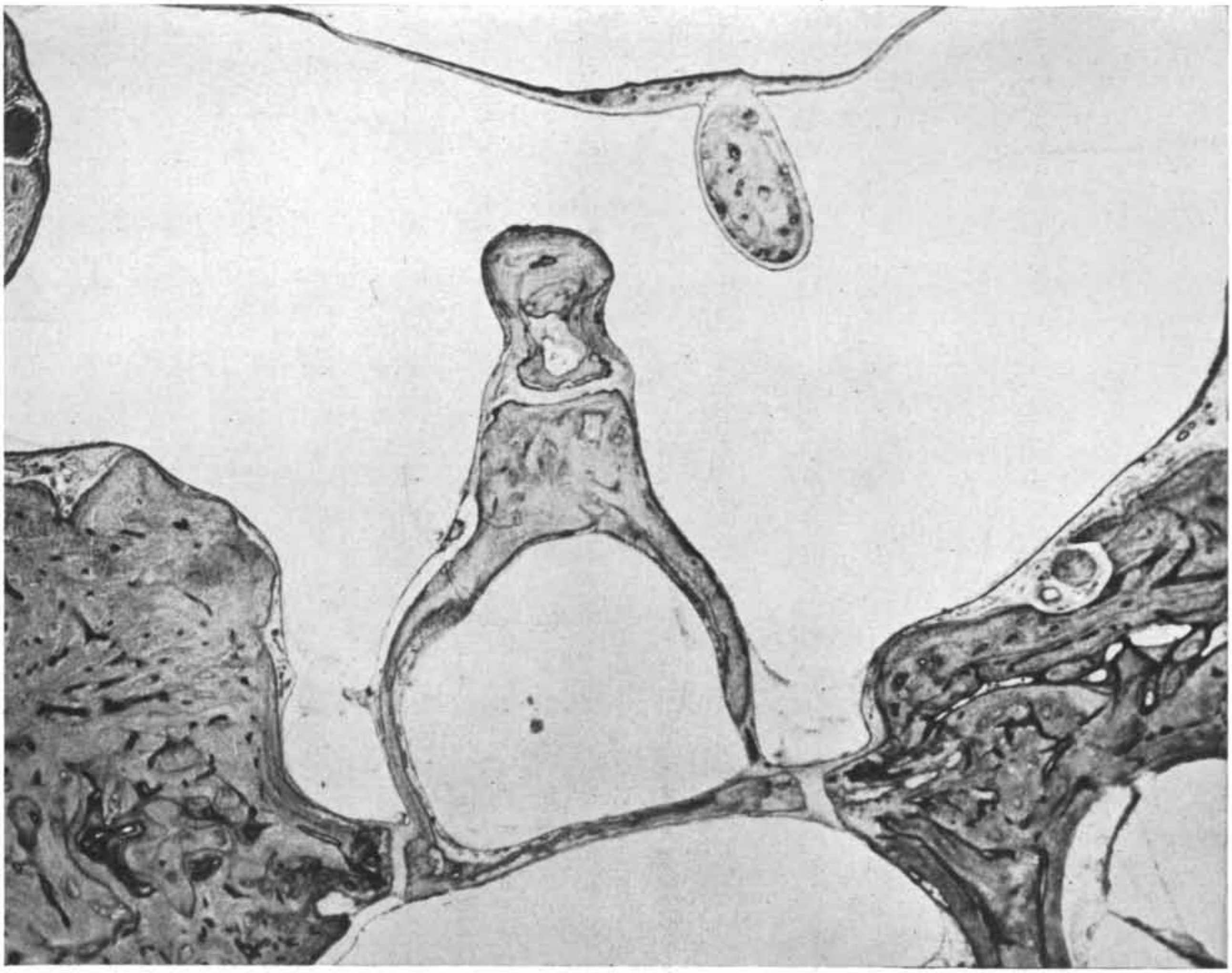
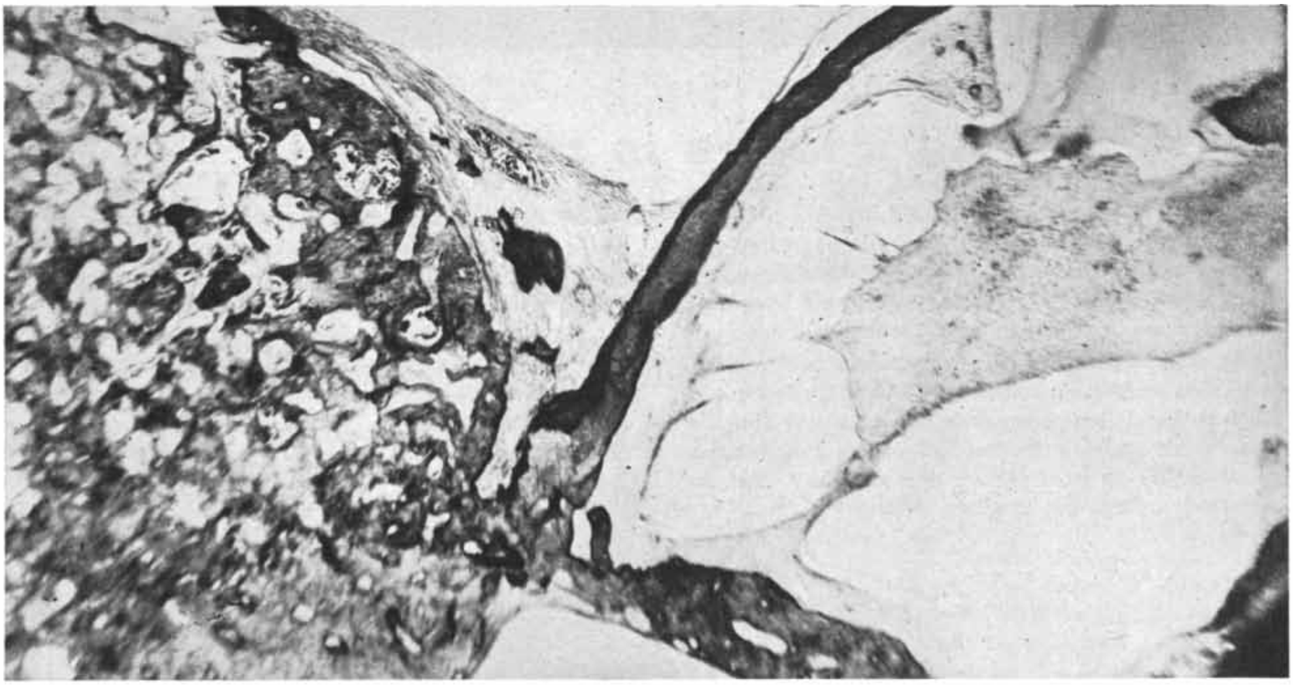




STIRRUP of the normal human ear is enlarged 19 times in the photograph at the top of this page. The thin line at the top of the photograph is the tympanic membrane seen in cross section. The hammer and anvil do not appear. The narrow membrane around the footplate of the stirrup may be seen as a translucent area between the footplate and the surrounding bone. The photograph at the bottom shows the immobilized footplate of an otosclerotic ear. In this photograph only the left side of the stirrup appears; the footplate is the dark area at the bottom center. The membrane around the footplate has been converted into a rigid bony growth.

more often in women than in men and seems to be accelerated by pregnancy.

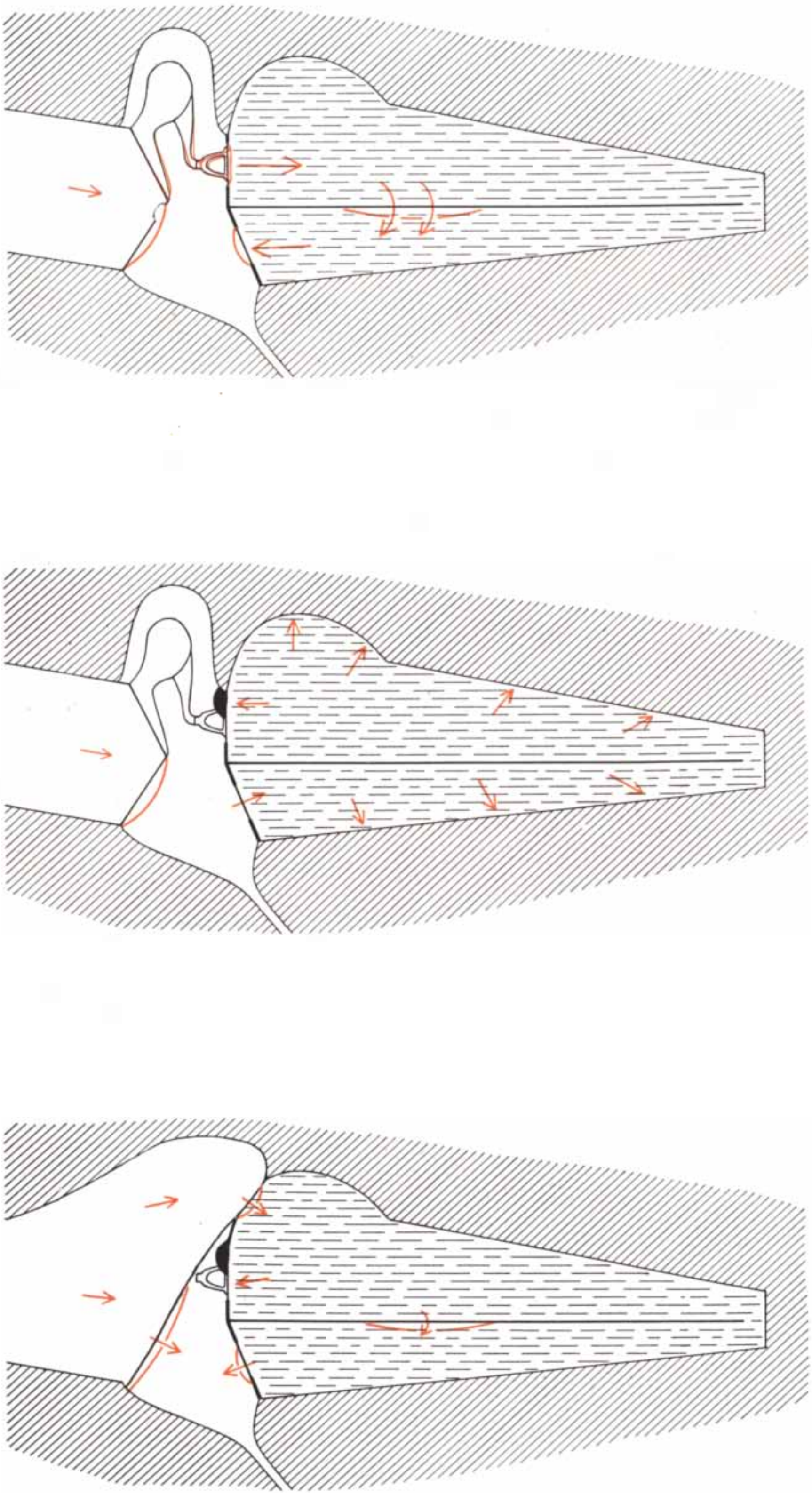
Immobilization of the stirrup blocks the hearing of air-borne sound but leaves hearing by bone conduction unimpaired. This fact is used for diagnosis. A patient who has lost part of his hearing ability because of otosclerosis does not find noise disturbing to his understanding of speech; in fact, noise may even improve his discrimination of speech. There is an old story about a somewhat deaf English earl (in France it is a count) who trained his servant to beat a drum whenever someone else spoke, so that he could understand the speaker better. The noise of the drum made the speaker raise his voice to the earl's hearing range. For the hard-of-hearing earl the noise of the drum was tolerable, but for other listeners it masked what the speaker was saying, so that the earl enjoyed exclusive rights to his conversation.

Difficulty in hearing air-borne sound can be corrected by a hearing aid. Theoretically it should be possible to compensate almost any amount of such hearing loss, because techniques for amplifying sound are highly developed, particularly now with the help of the transistor. But there is a physiological limit to the amount of pressure amplification that the ear will stand. Heightening of the pressure eventually produces an unpleasant tickling sensation through its effect on skin tissue in the middle ear. The sensation can be avoided by using a bone-conduction earphone, pressed firmly against the surface of the skull, but this constant pressure is unpleasant to many people.

Operations

As is widely known, there are now operations (*e.g.*, "fenestration") which can cure otosclerotic deafness. In the 19th century physicians realized that if they could somehow dislodge or loosen the immobilized stirrup footplate, they might restore hearing. Experimenters in France found that they could sometimes free the footplate sufficiently merely by pressing a blunt needle against the right spot on the stirrup. Although it works only occasionally, the procedure seems so simple that it has recently had a revival of popularity in the U. S. If the maneuver is successful (and I am told that 30 per cent of these operations are) the hearing improves immediately. But unfortunately the surgeon cannot get a clear look at the scene of the operation and must apply the pushing force at random. This makes the operation something of a gamble, and the patient's hearing may not only fail to be improved but may even be reduced. Moreover, the operation is bound to be ineffectual when a large portion of the footplate is fixed. There are other important objections to the operation. After all, it involves the breaking of bone, to free the adhering part of the stirrup. I do not think that bone-breaking can be improved to a standard procedure. In any case, precision cutting seems to me always superior to breaking, in surgery as in mechanics. This brings us to the operation called fenestration.

For many decades it has been known that drilling a small opening, even the size of a pinhead, in the bony wall of the inner ear on the footplate side can produce a remarkable improvement in hearing. The reason, now well understood, is quite simple. If a hole is made in the bone and then covered again with a flexible membrane, movements of the fluid in, for instance, the lateral canal of the vestibular organ can be transmitted to the fluid of the inner ear, and so vibrations are once again communicable from the middle to the inner ear. In the typical present fenestration operation the surgeon bores a small hole in the canal wall with a dental drill and then covers the hole with a flap of skin. The operation today is a straightforward surgical procedure, and all its steps are under accurate control.

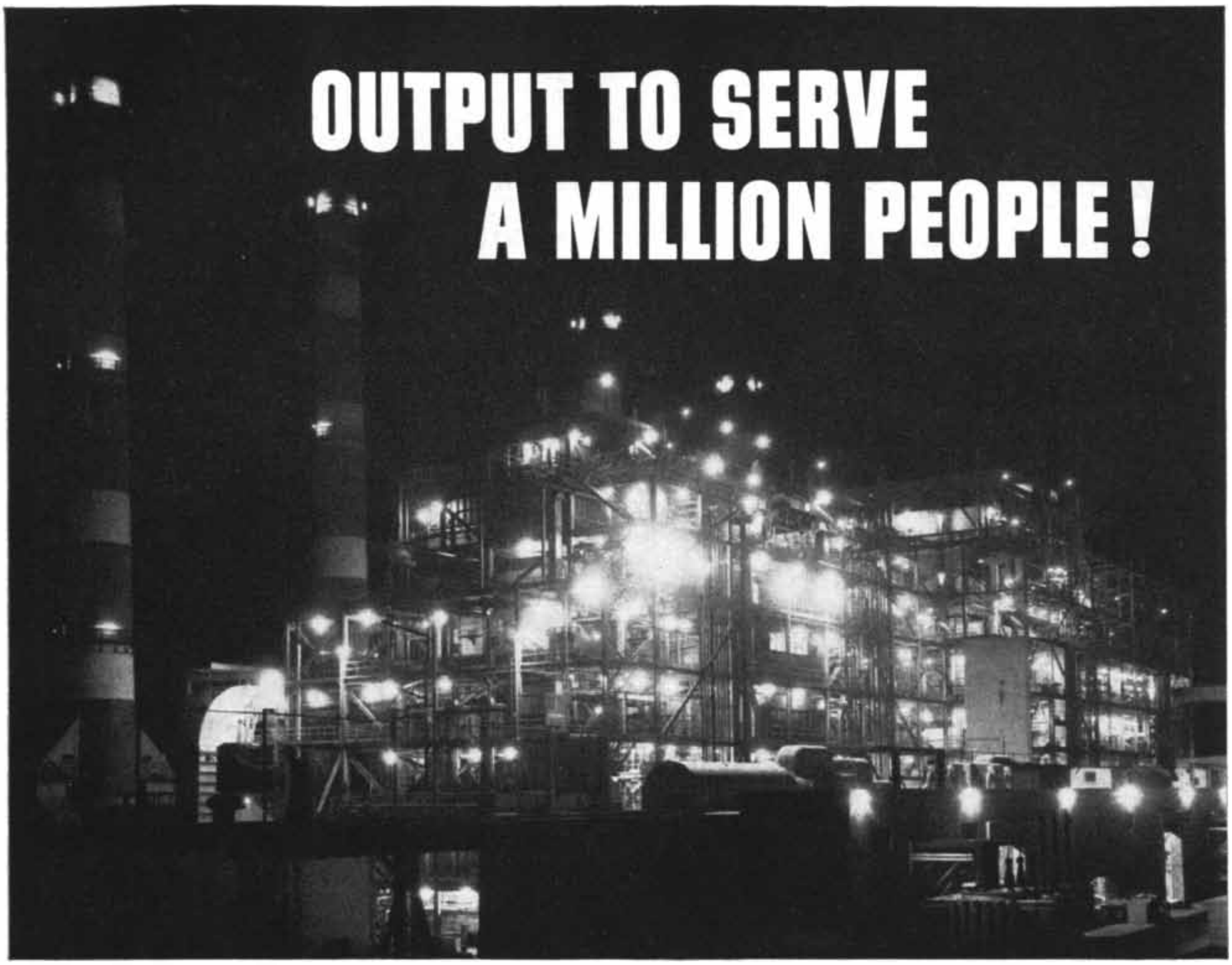


FENESTRATION OPERATION can alleviate the effects of otosclerosis. The drawing at the top schematically depicts the normal human ear as described in the caption for the illustration on pages 72 and 73. The pressure on the components of the ear is indicated by the colored arrows. The drawing in the middle shows an otosclerotic ear; the otosclerotic growth is represented as a black protuberance. Because the stirrup cannot move, the pressure on the tympanic membrane is transmitted to the organ of Corti only through the round window of the cochlea; and because the fluid in the cochlea is incompressible, the organ of Corti cannot vibrate. The drawing at the bottom shows how the fenestration operation makes a new window into the cochlea to permit the organ of Corti to vibrate freely.

Hazards to Hearing

I want to conclude by mentioning the problem of nerve deafness. Many cases of nerve deafness are produced by intense noise, especially noise with high-frequency components. Since there is no cure, it behooves us to look out for such exposures. Nerve deafness creeps up on us slowly, and we are not as careful as we should be to avoid exposure to intense noise. We should also be more vigilant about other hazards capable of producing nerve deafness, notably certain drugs and certain diseases.

We could do much to ameliorate the tragedy of deafness if we changed some of our attitudes toward it. Blindness evokes our instant sympathy, and we go out of our way to help the blind person. But deafness often goes unrecognized. If a deaf person misunderstands what we say, we are apt to attribute it to lack of intelligence instead of to faulty hearing. Very few people have the patience to help the deafened. To a deaf man the outside world appears unfriendly. He tries to hide his deafness, and this only brings on more problems.



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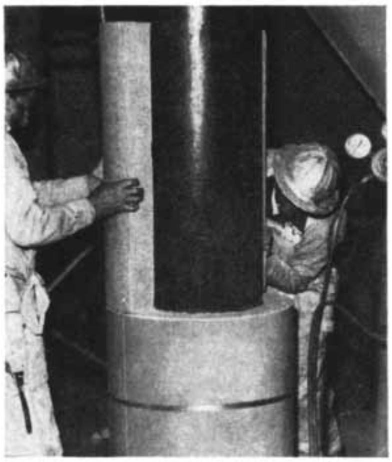

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THE PLASMA JET

Magnetohydrodynamic effects in an electric arc generate a beam of electrons and ions with a temperature of 30,000 degrees F., the highest maintained beyond an instant by a man-made device

by Gabriel M. Giannini

Nuclear technology during the past decade has begun to accustom us to the notion of temperatures of millions of degrees. There is even bold talk of controlled thermonuclear reactions in the hundred-million degree range, and the first laboratory skirmishes on this front are already under way. But we shall have to learn to walk before we can fly in these regions. Nuclear reaction temperatures are many thousands of times higher than the highest we have hitherto put to productive use. Between the chemical-reaction temperatures we now employ and the temperatures of fission and fusion there is a vast intermediate area to be explored. It is a region that holds interest for scientists and engineers in fields as diverse as astrophysics and aerodynamics.

The top limit of chemical temperatures is about 10,000 degrees Fahrenheit. This limit is fixed by the energy available in the chemical bond, just as the much higher temperatures of nuclear reactions bespeak the huge amounts of energy in the binding force of the nucleus. Above 10,000 degrees atoms can no longer hold one another by the hand, so to speak. In their violent random motion all molecular bonds are broken, and even the most refractory substances are vaporized. The collisions of atoms jar their electrons loose, and the vapor becomes a mixture of free electrons and positively charged ions as well as neutral atoms. The electrons collide with one another and with the ions, generating radiant energy and making the vapor glow with increasing brilliance as the temperature ascends. A cloud of matter in this perturbed state is called a plasma. Its behavior involves complex interactions between electromagnetic and mechanical forces and is the concern of the still far-from-complete theory of magnetohydrodynamics. It is also under very active laboratory exploration at the present time.

We may take some reassurance, as did Molière's M. Jourdain upon his introduction to prose, from the discovery that we have been using plasmas all along. Plasma is present in any electrical discharge in a gas: it consists of the charged particles that transport the charge across the gap. Thus the blinding light of an arc comes from a plasma; so does the luminous glow of a neon tube. The stream of electrons and ions in a vacuum tube can be considered a plasma; so can the ionized gas that excites the phosphors in a fluorescent lamp. But most of these devices operate at comparatively low temperatures. The plasma domain really begins above 20,000 degrees, where an appreciable percentage of the atoms begins to be ionized.

Technology is already edging across the lower boundary of this domain. At sufficiently high Mach numbers a rocket will generate a 20,000- to 50,000-degree plasma in the shock wave that travels with it in the air, just as a meteor in the atmosphere creates the glowing plasma that marks its wake. The fabrication of materials to withstand such temperatures is pushing the working heat of modern metallurgy and ceramics beyond the reach of chemistry. In the next higher range of plasma temperatures the first experiments toward a controlled thermonuclear reaction are going forward. Since no conceivable material will withstand the temperature of these reactions, the hope is to contain them in a "magnetic bottle" that will take advantage of the plasma's response to electromagnetic forces.

These ventures in applied science all involve fundamental questions which apply to the great bulk of matter in the universe. Obviously plasma behavior must underlie much of the internal dynamics of stars. The theory of magnetohydrodynamics itself had its beginnings in the pure science of astrophysics. It was first developed to explain certain motions within galaxies, the galaxies being treated by the theory as a gas of stars and dust encompassed in electrical and magnetic fields of truly huge dimensions in terms of space, time and energy content.

Laboratory experimenters have employed various stratagems to attain very high temperatures. However, these methods generally reach the high temperatures only momentarily and usually under special conditions of pressure. Investigators connected with Project Sherwood, which comprises the thermonuclear power program, have publicly reported experiments with short-lived clouds of plasma generated electrically inside low-pressure chambers. Henry Norris Russell of Princeton University used to observe exploding wires, instantaneously vaporized at about 15,000 degrees F. by sudden surges of current. Other investigators have achieved temperatures of 40,000 degrees F. and higher by means of the shock tube, in which a shock wave passes through a rarefied gas. But the shock wave travels down the tube as swiftly as a shell traveling in a gun barrel, and the high temperature lasts only a small fraction of a second.

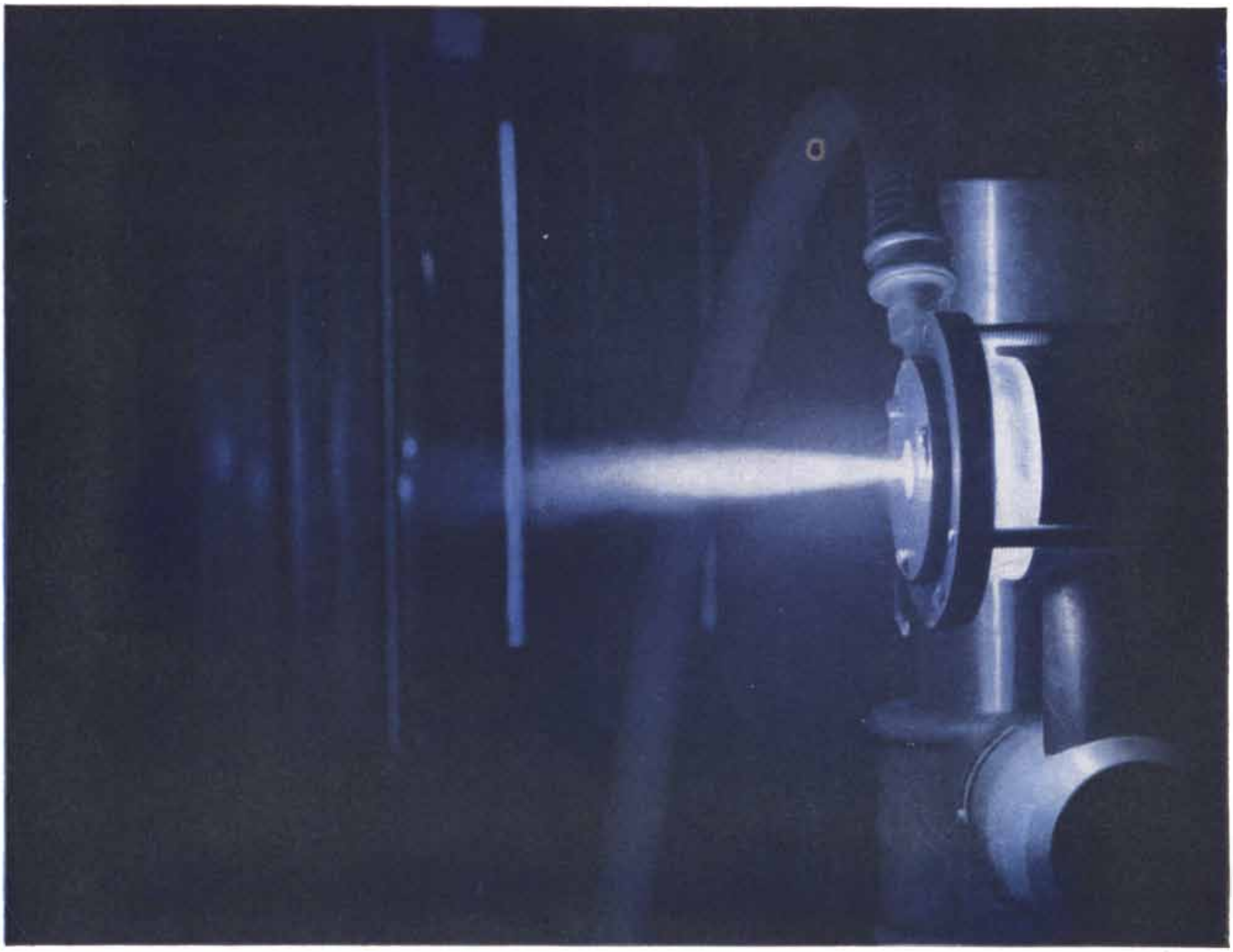
This article is concerned with a device which generates a jet of plasma at ordinary atmospheric pressure in the 15,000-to-30,000-degree range and maintains it for periods long enough for any experimental purpose. Essentially the device is an electric arc incorporating an ingenious cooling system which at once keeps the electrodes from vaporizing and helps to elevate the temperature of the plasma. Originated by H. Gerdien in Germany in the 1920s, this plasma generator has been under development in the U. S. at the Knolls Research Laboratories of the General Electric Company and in my laboratory at Santa Ana, Calif.

To see how the device attains its high temperatures, let us consider first how an ordinary arc converts electrical energy into heat. The process begins when the switch is thrown and the voltage drop across the arc gap extracts the first few electrons from the surface of the cathode. The electrons gain kinetic energy from the field and move at accelerating speed toward the anode. But before they have traveled far, they collide with the atoms and molecules of air in the gap and give up part of their kinetic energy to them. In these collisions some of the atoms are ionized, yielding additional electrons to be accelerated in the field. Once a trickle of electrons finds its way across the gap, the extraction of electrons from the cathode proceeds in much larger volume. The gas in the gap is now a plasma. It contains a stream of electrons flowing from the cathode to the anode and a countercurrent of ions flowing toward the cathode. Collisions between electrons and the larger particles become more frequent; these collisions transfer the kinetic energy of the electrons to the other particles, and the gas warms up. The energy of the electrons is transformed also into the energy of ionization, part of this energy being radiated as quanta of light when the electrons and ions reunite to form neutral atoms. The plasma at this stage is the kind we see in a spark; it contains only electrons and ions of the air.

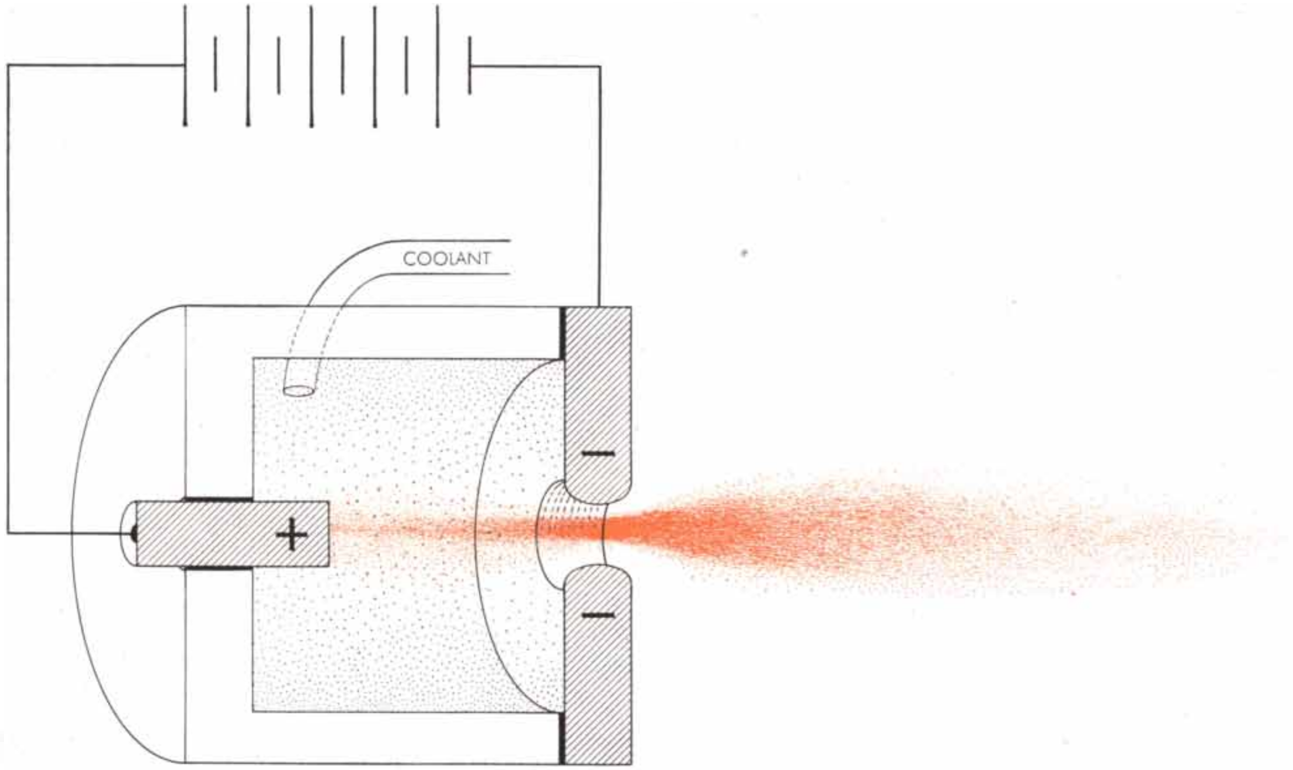
As the conductivity of the plasma rises, the stream of electrons impinging on the anode begins to heat it up. Soon positive ions are freed from the anode's surface and begin to move across the electric field toward the cathode. With the appearance of this hot gas of anode material in the plasma we now observe an arc. If it is a welding arc, the plasma will be rich in electrode materials and its temperature will be in the neighborhood of 7,500 degrees.

This temperature can be raised a little by increasing the voltage or the current, which is to say, the speed or the number of the electrons or both. But such investment of electrical energy, under ordinary circumstances, goes principally to producing a larger volume of plasma, not to a proportional elevation of temperature.

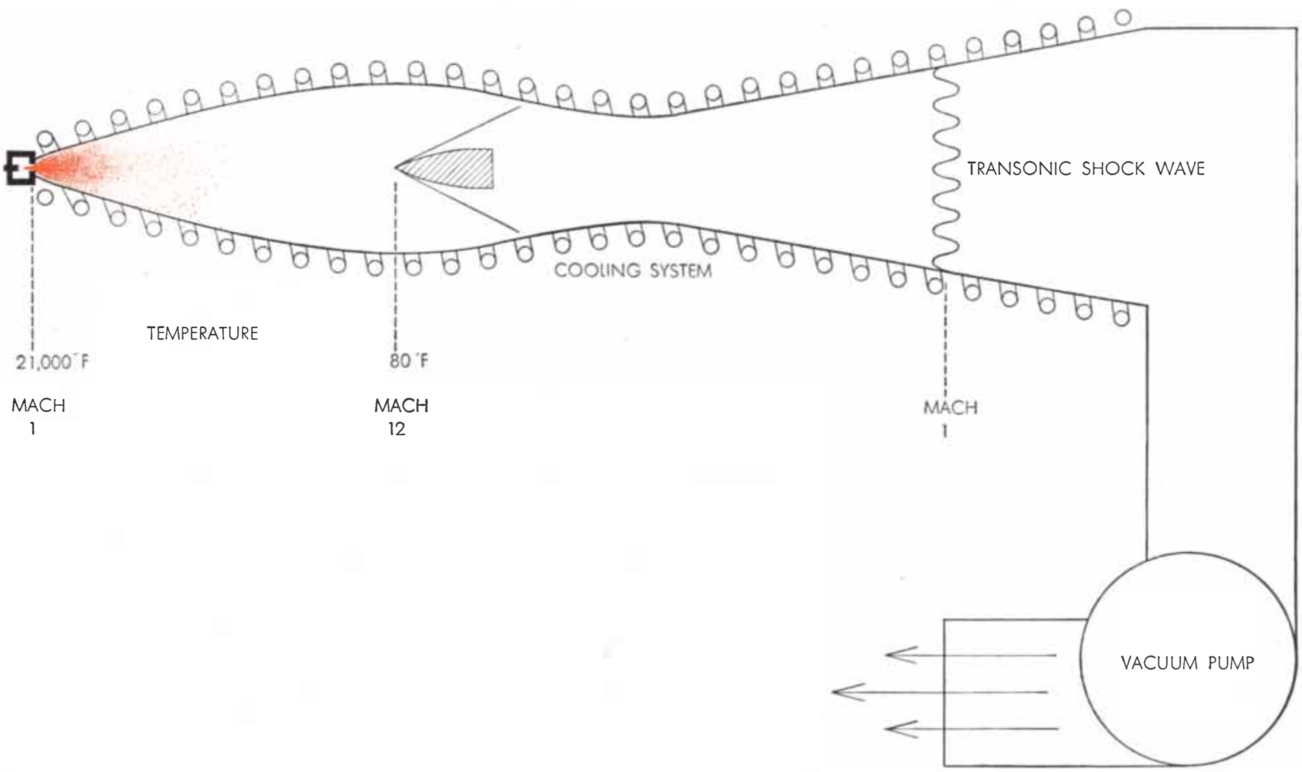
Here it should be stated with emphasis that the temperature of a plasma does not give us a meaningful description of the heat it contains, because the various particles may be in widely different energy states, especially when their density is low. The reading becomes valid only



PLASMA JET develops and maintains temperatures of 15,000 to 30,000 degrees Fahrenheit. The jet is a beam of electrons and the positive ions of the electrode materials and of the fluid, water or a noble gas, which cools the discharge (*see diagram on next page*).



PLASMA GENERATOR produces a high-current electrical arc enclosed in a small chamber. Water or a noble gas, injected into the chamber to cool it, makes the arc hotter by inducing two effects. The cooling makes the outer region of the arc less conductive and so, by a "thermal pinch" effect, constricts the current. A magnetohydrodynamic pinch effect then constricts the current further, bringing the plasma to extreme temperature. Magnetohydrodynamic forces and pressure eject the plasma through the orifice at right.

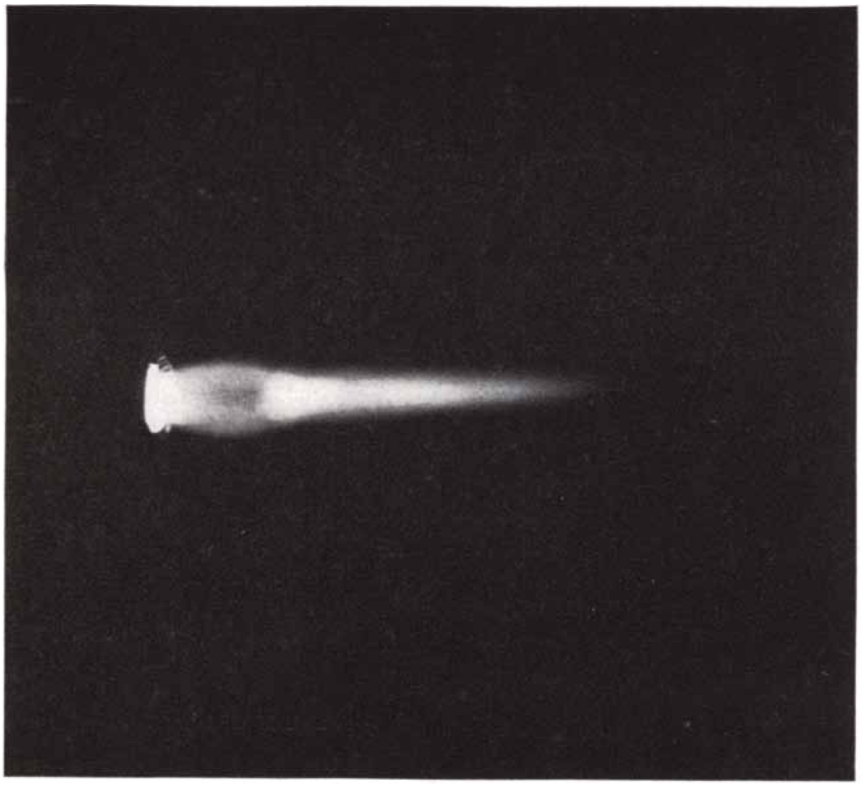


HYPERTHERMAL WIND TUNNEL for the study of magnetohydrodynamic effects in high-speed flight at extreme altitude is diagrammed. Plasma of a noble gas is injected (*left*) at the velocity of sound into the tunnel, which is pumped down to high vacuum. The gas, recombining as its temperature drops, attains 12 times the speed of sound in the test section (*center*). The shock wave generated at the test object momentarily ionizes the gas back into a plasma. Another shock wave (*right*) appears as the gas slows down.

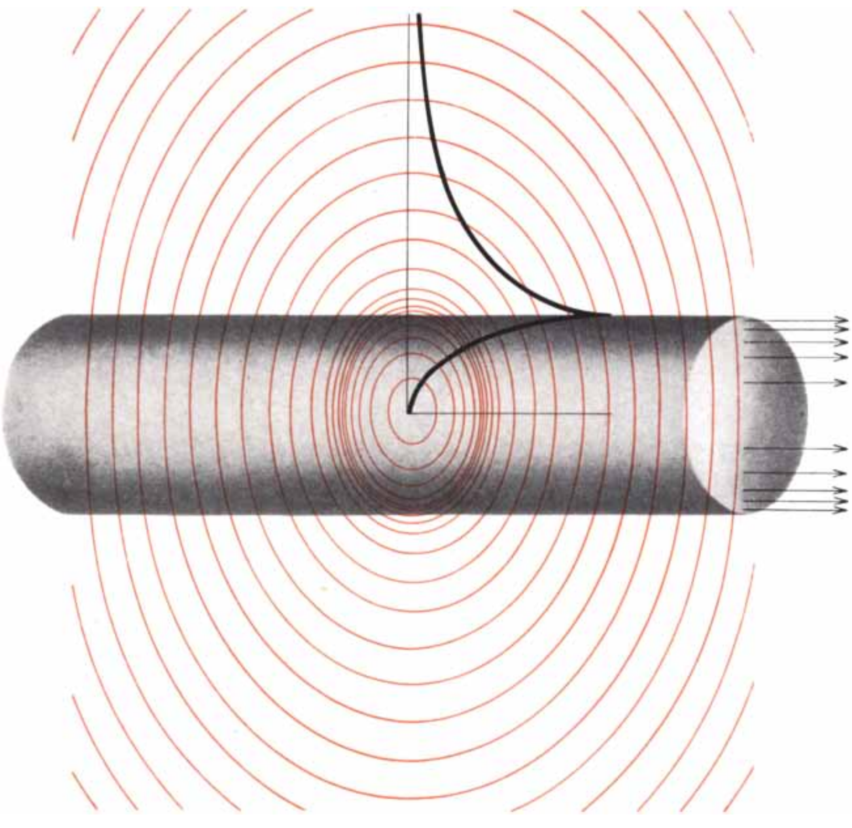
when the ions and neutral atoms have been brought up to the same level of kinetic energy as the electrons. This energy equilibrium is rarely attained in ordinary plasmas, and in the initial phases of an electrical discharge the electrons are always a great deal "hotter." The quotation marks are used here advisedly, because the motion imparted to the electrons by the electrical field has direction, whereas the essence of heat is random motion. However, the theory of plasmas (whose foundations were laid by Irving Langmuir in the 1920s) permits us to translate the kinetic energy of electrons into a temperature equivalent: one electron volt—that is, the acceleration of an electron through a voltage drop of one volt—corresponds to a temperature of about 20,000 degrees. It takes only a little energy to make electrons very hot. This is because they are such light particles. The heating of the other particles in a plasma presents a more difficult task. They get their heat from collision with the electrons. Because they are so much more massive, it takes a high frequency of collisions to kick them up to their corresponding level of kinetic energy. When this energy equilibrium is attained, the plasma has reached the highest temperature obtainable with a given input of electrical energy.

All this suggests that if we want to increase the temperature of an arc we should do something to increase the frequency of collisions in the plasma. This reasoning is supported, in reverse, by the cool temperature of a neon tube. There the collision rate is low (because of the low gas density), the plasma is nowhere near equilibrium, and very little electric energy is converted into heat. On the other hand, experiment shows that the temperature of an arc can be raised considerably by producing it in a gas under high pressure in a vessel. The higher density of the gas increases the frequency of collisions and so pushes the ions up to equilibrium temperature.

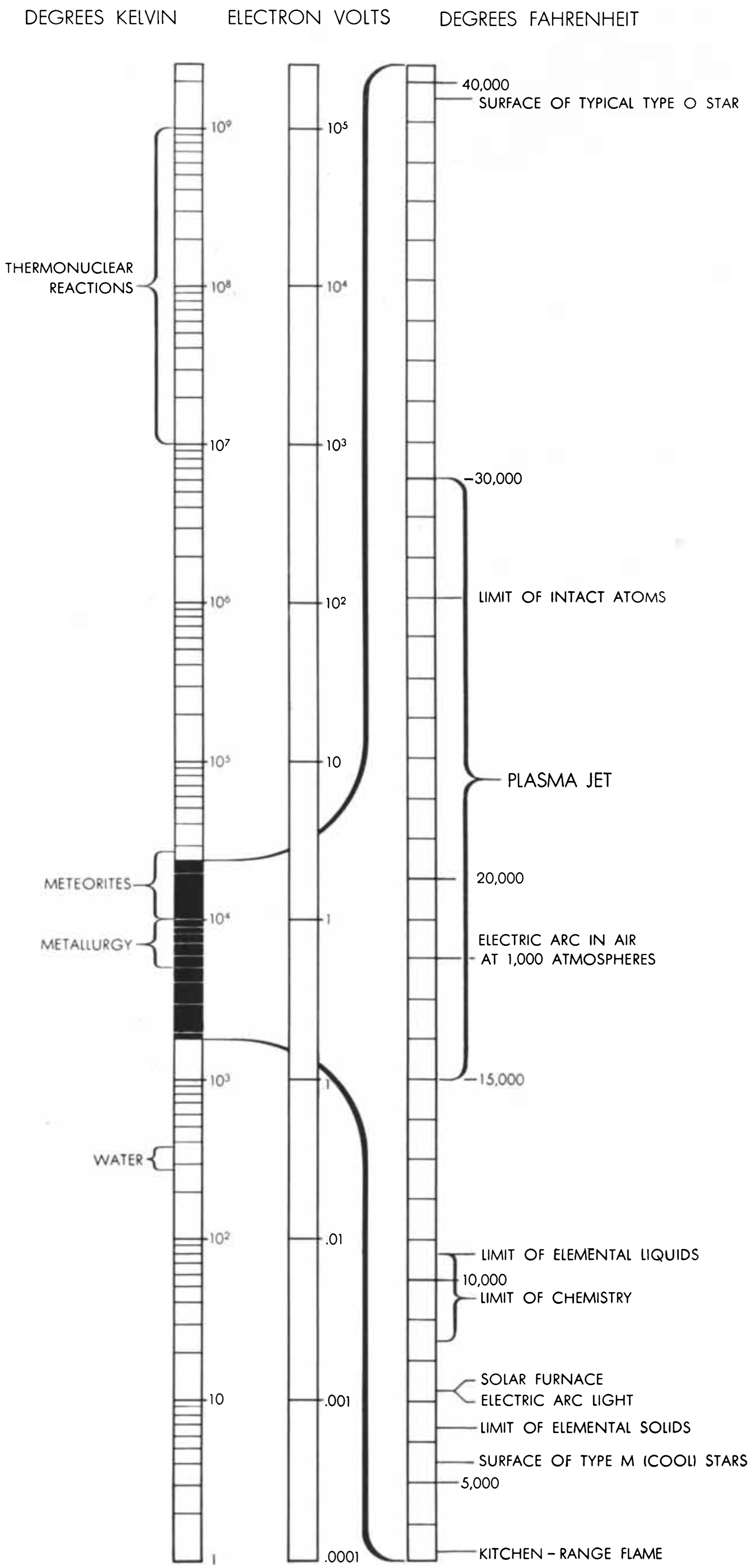
The plasma generator we are concerned with here achieves its high temperatures by this means but without the encumbrance of enclosing the arc within a pressure vessel: it employs thermal and magnetohydrodynamic effects to put the plasma under pressure and increase its density. The arc is struck inside a small cylindrical chamber made of glass or metal [*see drawing on opposite page*]. One end of the chamber is an electrode—a flat plate of carbon or other conducting material, perforated at its center to provide an orifice for the plas-



PINCH EFFECT, visible in this photograph, constricts plasma jet so that jet is pulled away from the orifice in the electrode, an incidental effect which keeps electrode from melting.



MAGNETIC FIELD, self-induced by stream of plasma, causes pinch effect. Field reaches maximum density at edge of the plasma, as indicated by concentric circles and by curve.

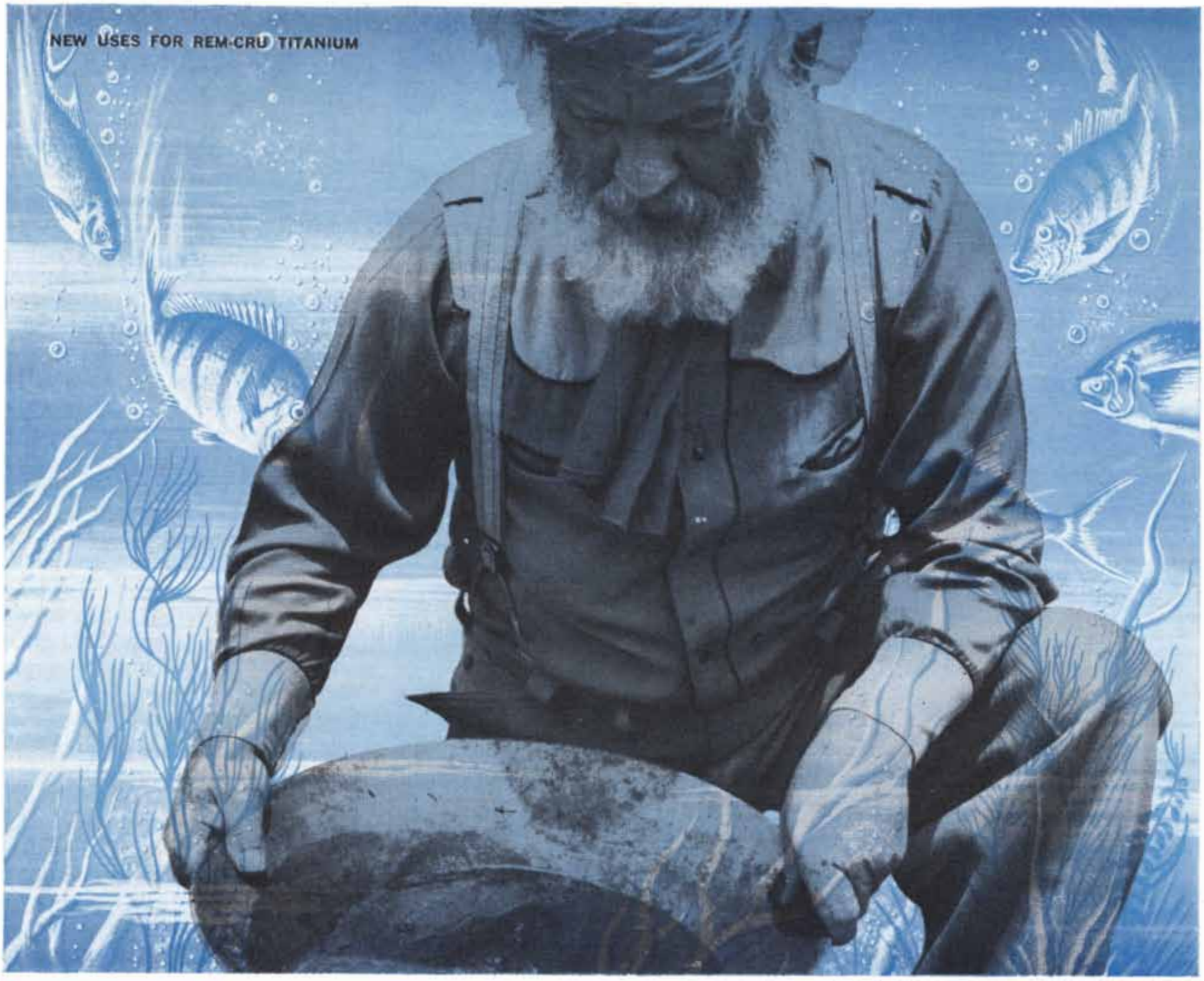


ma jet. It is obvious that this piece of apparatus would be quickly melted down by an arc of only respectable temperature if it were not somehow cooled. Cooling is provided by a jet of water or gas injected tangentially into the chamber. The arc is thus contained within a fluid vessel—a cushion of high-pressure steam or gas which forms between it and the walls of the chamber.

This fluid vessel not only keeps the chamber cool but also cools the gases in outer regions of the plasma. Because the cooling lowers the ionization and hence the conductivity of the gases in the outer regions, the current in the discharge tends to concentrate in the hotter central region of the plasma. This increase in current density, by what may be called a thermal pinch effect, brings a further increase in temperature and conductivity. When the current density in the center of the discharge reaches a high enough value, a second pinch effect takes over. This is the magnetic pinch, about which there has been talk in connection with thermonuclear power projects. As Michael Faraday showed more than a century ago, two parallel conductors through which currents flow in the same direction will be attracted to each other by their self-induced magnetic fields. The charged particles in the chamber of the plasma jet behave the same way. They crowd closer together in their self-induced magnetic field and so constrict the discharge even further, bringing the plasma to higher density. The combination of electromagnetic forces and high pressure now developed in the chamber ejects the plasma from the orifice in a foot-long beam of highly excited particles too brilliant to look at with unprotected eyes.

In the air in front of the orifice the jet gives up to its surroundings the energy that generated it. Part of it is true heat energy and is dissipated as such by conduction and radiation. Some of it is kinetic energy, contained in the directed movement of the mass of plasma as a whole; this energy too is dissipated as heat. Additional energy is represented in the ionization of the plasma; as the ions recapture electrons, part of this energy

RANGE OF TEMPERATURES attained by the plasma jet is located on the scale of degrees Fahrenheit at right. The range of temperatures on the Fahrenheit scale is related to the scale of degrees Kelvin (degrees centigrade from absolute zero) at left. The kinetic-energy equivalents of degrees Kelvin is given in electron volts in center.



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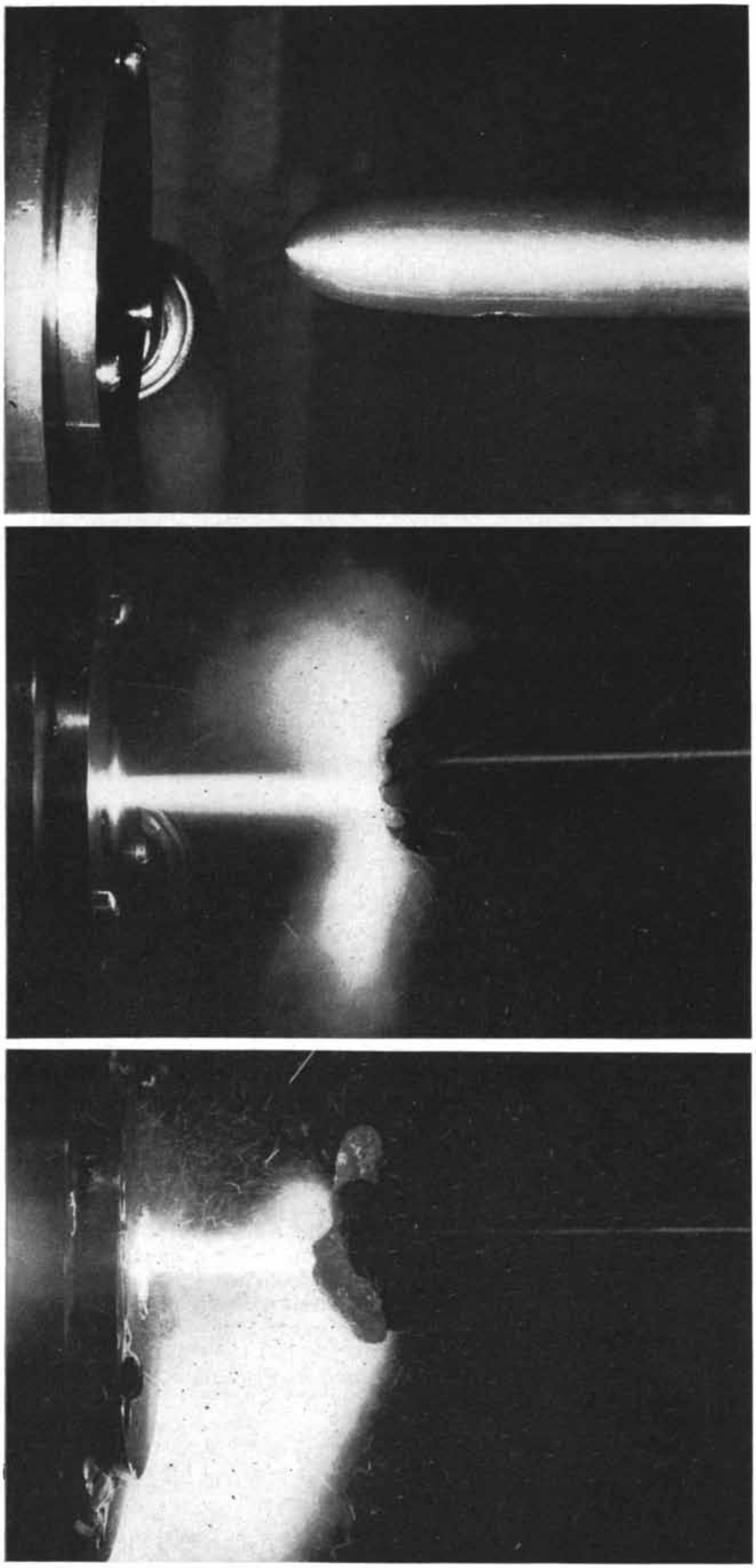

METAL IS VAPORIZED by jet in these photographs made between one and two seconds apart. The jet temperature exceeds not only melting but also boiling points of the elements.

is given up in the form of radiations which may range from radio frequencies to the far ultraviolet. A significant component of the radiation from the plasma is generated by electron-electron collisions—an indication of its high excitation.

With energy present in so many forms, no single measurement can tell us all we want to know about the energy contained in the plasma jet. The average temperature can be established by measuring the jet's thrust—a standard procedure developed for jet engines. Thrust is a function of the heat added to the gas, after due allowance for other factors. Spectroscopic studies also can give an indication of the temperature, and in addition yield information about the energy states of the various components of the plasma.

When the coolant is water and the electrodes are carbon, the cooler regions of the jet contain a wealth of chemical compounds, in addition to the elements nitrogen, oxygen, hydrogen and carbon. For some of the experimental and practical purposes about to be described, these chemical riches are an embarrassment. Recently we have succeeded in producing a plasma of a single noble gas, argon or helium, containing a minimum of contamination with electrode materials.

Now that we have a high-temperature plasma jet, what can we do with it? A first easy answer is: all of those things we have wanted to do with a chemical flame but could not because it is not hot enough. For example, cutting steel with a chemical flame usually requires two stages; the first to warm the material, the second to change its chemical structure. Thus an oxyacetylene flame heats the steel red-hot and then supplies an excess amount of oxygen to burn it. These two steps are not necessary when a plasma is employed; the material melts instantly. We shall soon be working with a whole new technology of materials which have so far resisted thermal attack. It will be possible to machine refractory metals in a much shorter time, to fuse and shape ceramics for the first time and to bond metals and ceramics together in ways that engineers have only dreamed of. Electric furnaces already operate in this temperature range, between 5,000 and 10,000 degrees, as do solar furnaces and certain special cutting flames, such as the oxy-aluminum and Thermit flames. The noble gas plasma, however, offers pure heat and even higher temperatures. Since we cannot merely melt but vaporize every existing material, the door is open for thermochemistry or plasma

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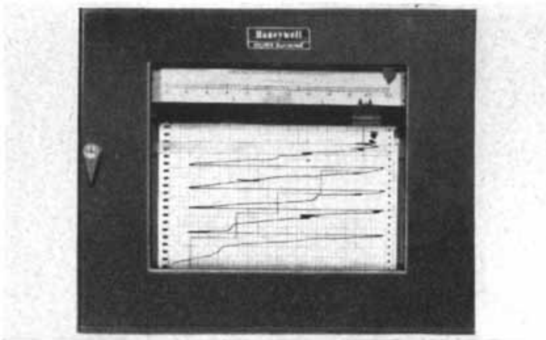

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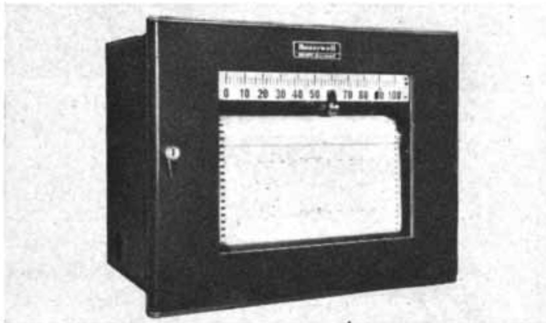

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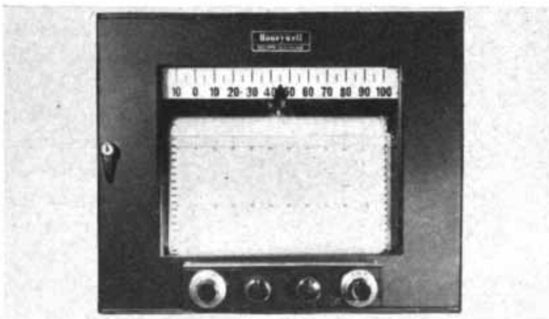

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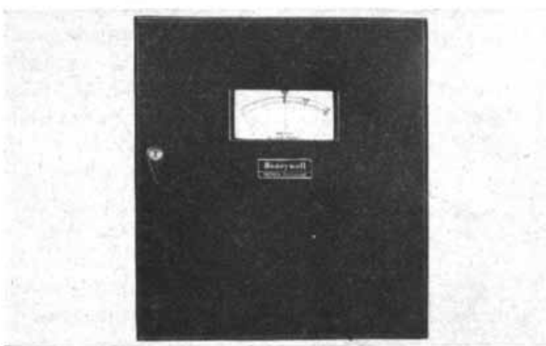

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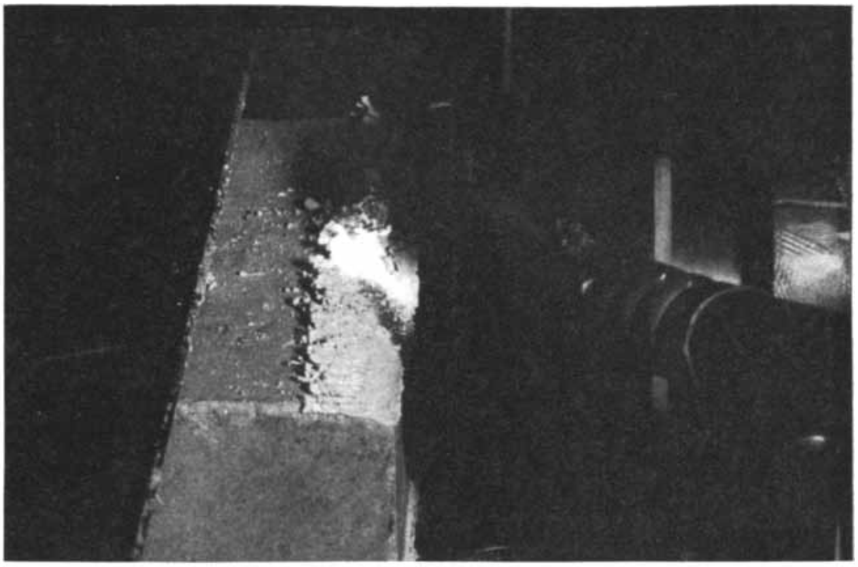

ZIRCONIA is fused by plasma jet of 10,000 degrees. One of the most refractory materials in use, zirconia is hard to work and shape; now it can even be melted on metals as a coating.

chemistry. This means, among other things, the alloying of metals via the vapor phase, that is, by vaporizing the metals individually and then letting them condense in appropriate order. Direct vaporization of a scarce material from its raw ore into fairly pure form is another prospect, and still another is purification of chemically active substances by controlled vaporization.

The plasma jet holds a different sort of interest for aerodynamicists concerned with the problems of high-speed flight. They are particularly interested in the plasmas generated in the shock waves of missiles. A plasma jet used to activate what may be called a hyperthermal wind tunnel [*see drawing on page 82*] will make it possible to study this otherwise inaccessible problem in the laboratory. An appropriate combination of atmospheric gases would be heated to, say, 30,000 degrees and then expanded and accelerated in the tunnel until it reaches a velocity 10 or 20 times that of sound. Upon meeting a solid body—a model of the shape or a sample of the material under investigation—the air stream will be rippled by a standing shock wave in which temperatures will approximate the original values.

The plasma jet will facilitate basic investigations in magnetohydrodynamics. With an abundant source of plasma at atmospheric pressure it will be possible to conduct a wide variety of experiments on the interaction of plasma flows with electrical and magnetic fields. As Arthur Kantrowitz observed in these pages ["Very High Temperatures"; SCIENTIFIC AMERICAN, September, 1954], plasmas accelerated by magnetic fields may provide a ready approach to the development of escape velocities for space rockets. Such experiments also have interest for the astrophysicist who wants to study the earth processes that go on in stars. Here temperatures of 50,000 degrees would be desirable. As plasma sources of still higher temperatures are developed, they should facilitate investigation of the thermonuclear power problem.

Speculation about these possibilities should be tempered by the understanding that the consumption of energy must go up much faster than temperature as we climb the temperature scale. As the plasma gets hotter, it loses an increasing percentage of its energy in the form of radiation. The dwelling time of energy in the particles gets shorter and shorter until, at 200,000 degrees, about nine tenths of the energy injected into a plasma is instantly re-radiated. It becomes as wasteful a process as trying to maintain a high air pressure in a leaky can. At these levels and above, duration of temperature must be sacrificed for increase.

At the moment the plasma jet I have described here generates the hottest temperatures that can be maintained practicably at atmospheric pressure. But there may be other devices already under development which will reach into far higher ranges of temperature and energy density, making this device look like a toy. The climb up the temperature scale that has now begun will bring opportunities still uncharted. It will teach us much about processes in the stars and give us a means of manipulating matter and energy in ways we have not yet imagined.

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SINGLE HUMAN CELLS IN VITRO

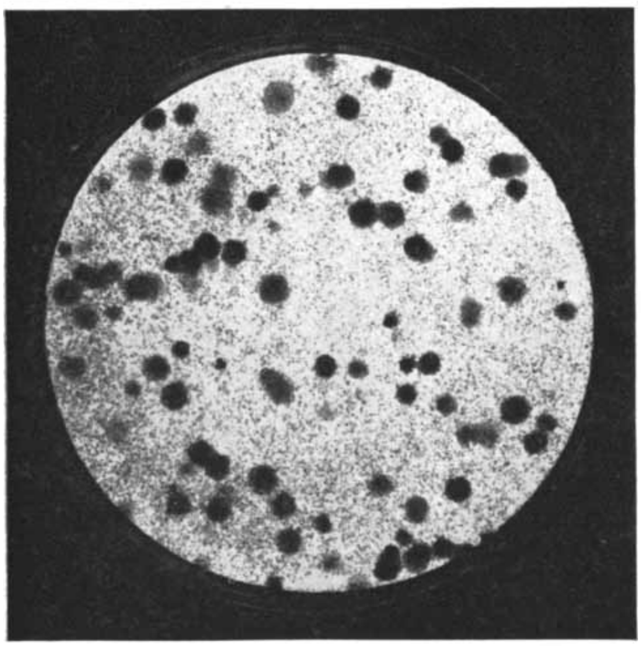
When a suspension of bacteria is spread on a layer of nutrient, each bacterium gives rise to a colony of genetically uniform descendants. The same thing can now be done with cells of various human tissues

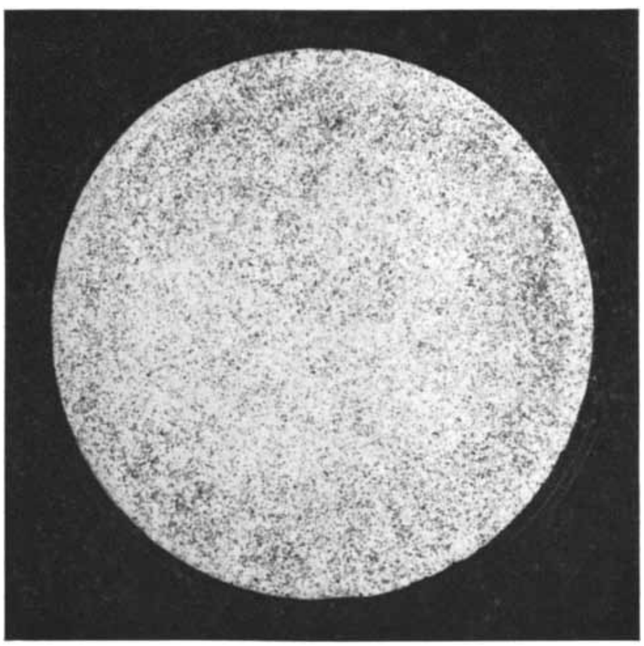
by Theodore T. Puck

The cell, the basic building block of all living things, may vary in details in different plants and animals, but it always has the same general design: a nucleus which directs its activities, a cytoplasm which houses its complex chemical machinery, and an enclosing wall which polices its interactions with the outside world. For some forms of life a single cell suffices as the entire body of the organism. This lone cell can take what it needs from the environment, reproduce its own kind and generate new evolutionary forms. At the other extreme, the enormously complex human organism needs some 10 million million cells, variously specialized to perform many different functions. Yet even these cells have a life of their own. We would like to study them as individuals. To understand the human organism we need to analyze the cells of which it is composed, just as, to understand the body politic, we must know something about the characteristics of the members who make it up.

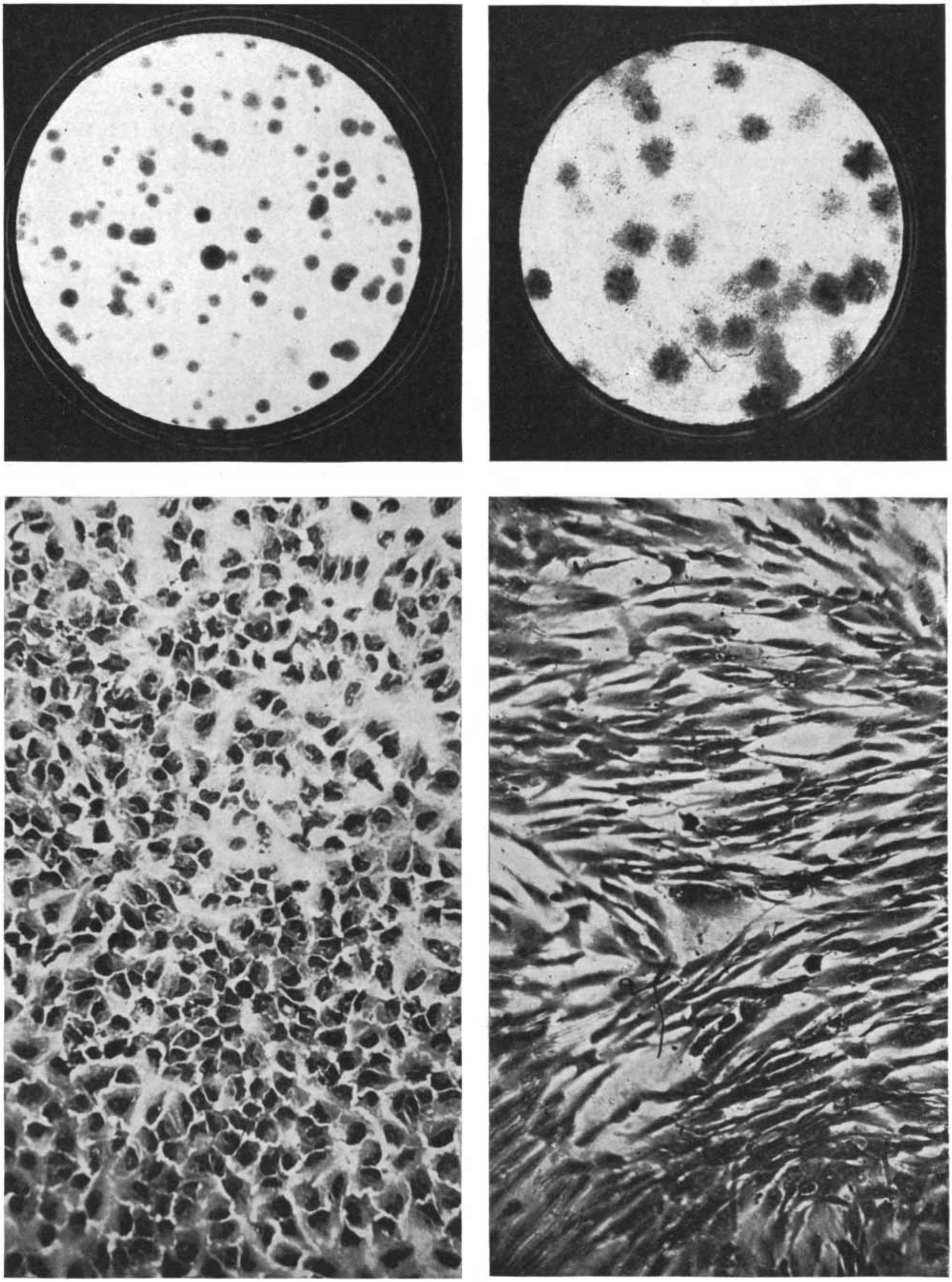
For investigating single-celled organisms, microbiologists have developed an elegantly simple and effective technique. Individual cells are spread out on a material such as agar, where they are immobilized, and each cell then multiplies to form a separate colony. This procedure permits precise measurement of the growth of single cells under various conditions. It has enabled biologists to learn a great deal about unicellular organisms (*e.g.*, bacteria): what specific nutrients they need; how they respond to temperature variations, to drugs, to radiation and to many other specific treatments; how they change genetically by mutation.

If we could apply the same methods to individual mammalian cells, we might begin to get answers to many fascinating and important questions. For instance, how dependent are human cells upon one another? Which types of cells, if any, can reproduce independently, and under what conditions? What happens when embryonic cells differentiate into specialized ones, and how is the change brought about? Do cells in the body change their genetic constitution? How does radiation affect them? What changes occur in the cells when the





COLONIES OF HUMAN TISSUE CELLS on plate at left resemble bacterial colonies. They are growing in a broth supplemented with "feeder" cells. The feeder layer (*right*) is made by exposing normal cells to small doses of X-rays, which destroy their ability to multiply but do not kill them. Under certain conditions normal cells need substances made by the feeder cells for their growth.



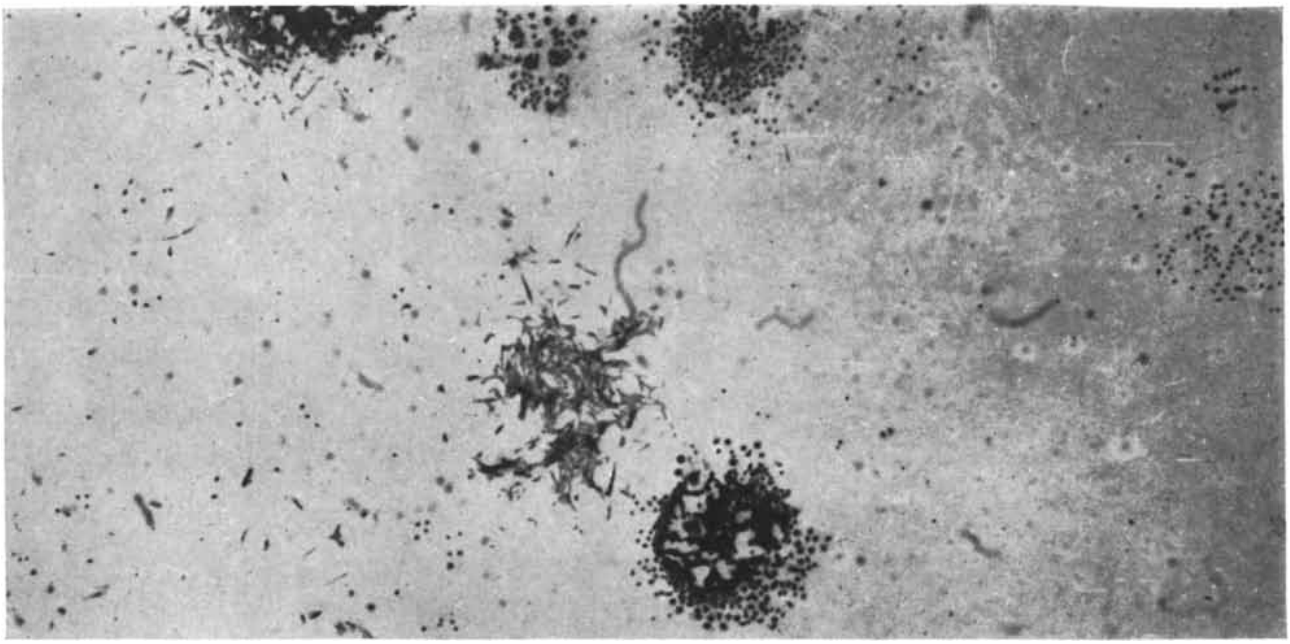
TWO KINDS OF COLONIES result from the culture of single human cells. At top left are colonies of epithelial cells from the eye. The colonies with fuzzy edges on the plate at top right were formed from fibroblastic cells from the skin. The photomicrographs below enlarge cells of the colonies. Epithelial cells (*left*) are close-packed. Fibroblastic cells (*right*) grow more loosely.

body ages, or when normal cells become cancerous? To explore such questions we need to be able to study the growth of isolated mammalian cells in the way that microbiologists have investigated microbes. Fortunately we now seem to be on the road to doing so. This article will describe some of the successful experiments in culturing individual mammalian cells which have been carried out in the department of biophysics at the University of Colorado by the writer and his associates, S. J. Cieciura, H. W. Fisher and P. I. Marcus.

As a starting point we had the benefit of a demonstration by Wilton R. Earle and his co-workers at the National Cancer Institute, who had succeeded in growing colonies from single mammalian cells sealed in tiny capillary tubes [see "Tissue Culture and Cancer," by John J. Biesele; SCIENTIFIC AMERICAN, October, 1956]. We set out to try to grow colonies by the plating method. Earle's group, analyzing their experiment, had concluded that mammalian cells would multiply only if the nutrient medium was conditioned in some way by cooperative action of the cells themselves. Therefore, to "condition" the medium we first laid down on the Petri dish a "feeder" layer of cells. We exposed these cells to small doses of radiation which destroyed their ability to multiply but not their metabolic activity (*e.g.*, their ability to consume glucose). The cells we used for our first experiments were human cancer cells, of the type named HeLa. On the feeder layer we deposited a small number of fully active cells which were capable of multiplying. The experiment was immediately successful. Every single cell produced a distinct colony whose population could be counted with reliable accuracy [*see photograph on page 91*].

We then looked into the functions served by the feeder cells and found that they did two things: (1) eliminated the need for some of the nutrients (*e.g.*, the sugar-like substance inositol) which human cells normally require for growth, and (2) neutralized the effect of inhibiting substances (*e.g.*, antibodies). With this knowledge we were able to go on to grow colonies without the use of a feeder layer. They grew with 100 per cent efficiency on Petri dishes containing only an enriched nutrient mixture, free of antibodies and other toxic agents.

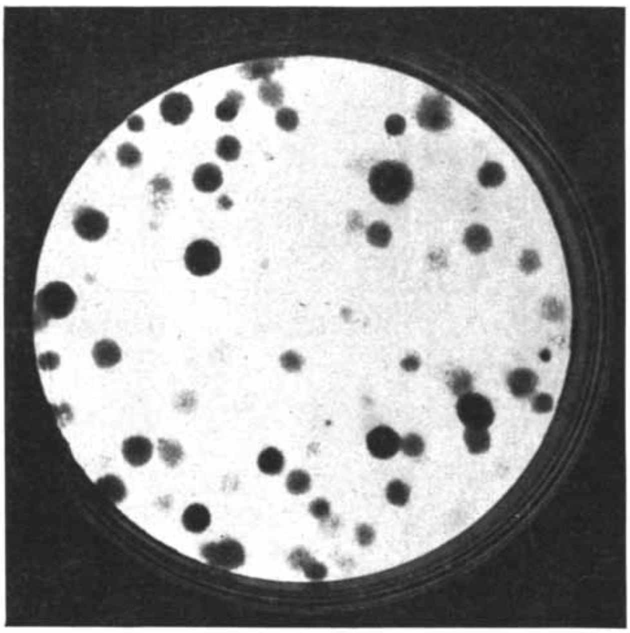
Human cells of the HeLa cancer type, then, could be cultured like bacteria. What about other body cells? Could colonies be grown from single human cells of normal types? We proceeded to

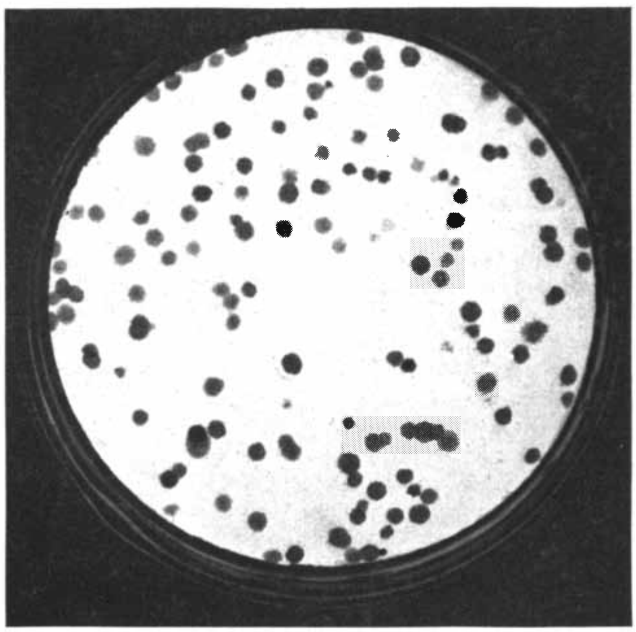


CELLS FROM A SINGLE PIECE OF TISSUE produce several types of colonies whose cells have different genetic traits. Colonies of fibroblastic cells such as the one near the center of the picture spread out because these cells tend to move along the glass. They grow so well in fluid enriched with embryo extracts that they may fill up all the space on the plate and crowd out the other cells.

test our method on many different kinds of human cells: cells from various organs (liver, kidney, lung, skin, muscle, bone marrow and so on), cells from young and old persons, fresh cells and cells which had grown for years *in vitro*, cells of normal and of diseased tissues. In every case, isolated single cells proved to have the capacity to multiply into colonies. Some types would grow only if a feeder layer of cells was provided; some multiplied with only 50 to 60 per cent efficiency because they were extraordinarily sensitive to toxic agents. The colonies produced by the different cells varied considerably in form and in other features [*see photographs on page 92*]. All these differences are interesting subjects for future study. But for the time being the most important fact is that the varieties of human cells can be cultured and experimented upon just as bacteria have been.

From daily counts of the multiplication of cells in the growing colonies we can plot a typical growth curve, which turns out to be exactly like the standard growth curve of colonies of bacteria [*see chart on page 96*]. First





COLONIES OF CANCER CELLS of the HeLa type (*left*) have a variety of shapes and sizes, suggesting that the culture actually contains a mixture of hereditary strains. This was proved by subculturing each type of colony, *i.e.*, spreading some cells of a single colony on a fresh plate. The resulting colonies (*right*) consist of cells from the same strain and have a more uniform appearance.

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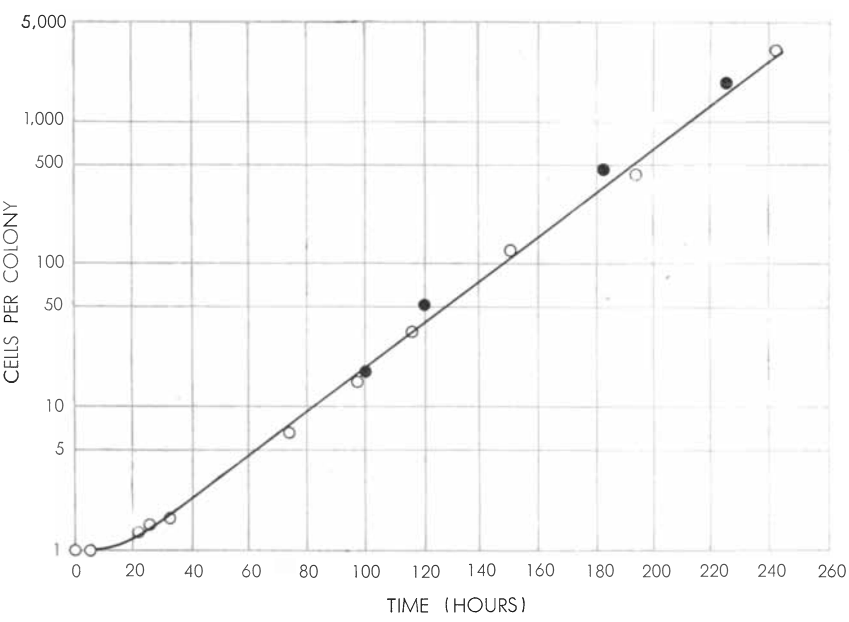
there is a delay of some hours: presumably the isolated cell is adapting itself to start growing in the new environment. Then it commences to multiply at a logarithmic rate. If provided with the appropriate nourishment, at approximately the human body temperature, the cell population doubles itself every 18 hours; this is called the "generation time." The colony continues to grow at this rate until one or more of the necessary nutrients is depleted or toxic conditions develop.

Now we can test the growth of each type of cell under any given conditions by four criteria: (1) the percentage of single cells that will produce colonies in the given situation; (2) the adjustment period needed by the cell before it starts growing; (3) the generation time, or rate of growth, and (4) the point at which the depletion of nutrients or the accumulation of toxic products stops this growth. With these several criteria, we can make a detailed analysis of the growth process. We can find out, for example, what aspects of the growth pattern are affected by agents which are supposed to slow down or speed up cell growth. One important fact that has emerged from the experiments is that the minimum generation time of human cells is 18 hours: that is, doubling of the number of cells every 18 hours is the maximum growth rate of human cells that we have been able to achieve in the most favorable environment we can provide in a Petri dish. Of the 18-hour generation period, only about 45 minutes is taken up by the process of cell division (mitosis) itself. This suggests that a human cell has to spend nearly 18 hours synthesizing certain molecules or rearranging its physical structure before it can divide.

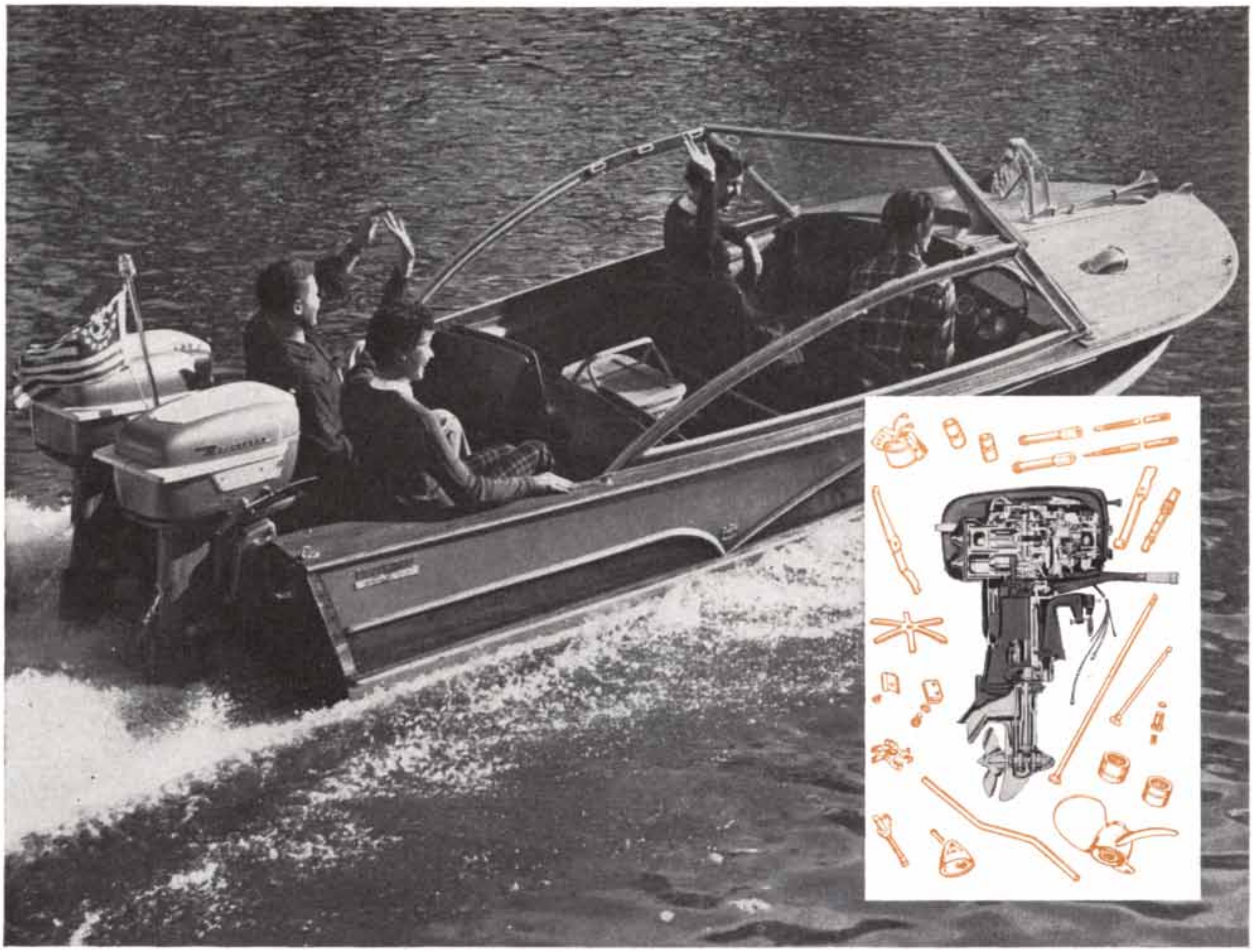
At first thought this growth rate may seem slow. Bacteria commonly multiply at the rate of once every 18 minutes, instead of 18 hours. But a mammalian cell has about 1,000 times the mass of a bacterial cell, so that on a weight basis mammalian cells actually manufacture new protoplasm considerably faster than the bacteria do.

At the 18-hour doubling rate, a single human cell would multiply to the number of cells in a newborn baby within about 30 days. Obviously most of the nine-month period for gestation of a baby is occupied not with sheer multiplication of cells at the fastest possible rate but with fashioning the diverse building units of a highly organized system.

We have been able to use the first of the four criteria listed above (the percentage of single cells that produce colonies on a plate, or what we call the "plating efficiency") as a precise measure of growth-inhibiting treatments. For instance, at 100 degrees Fahrenheit every cell will multiply into a colony. At 94 degrees the percentage drops considerably. Below 86 degrees no colonies at all develop. This extraordinary sensitiv-



GROWTH CURVE of HeLa-cell colonies was plotted on a logarithmic scale, using points from two sets of experiments (*dots and circles*). The cells require about 24 hours to become established (lag phase). Then they multiply at a steady rate (logarithmic phase) which can be maintained almost indefinitely if food supply of the cells is continually renewed.



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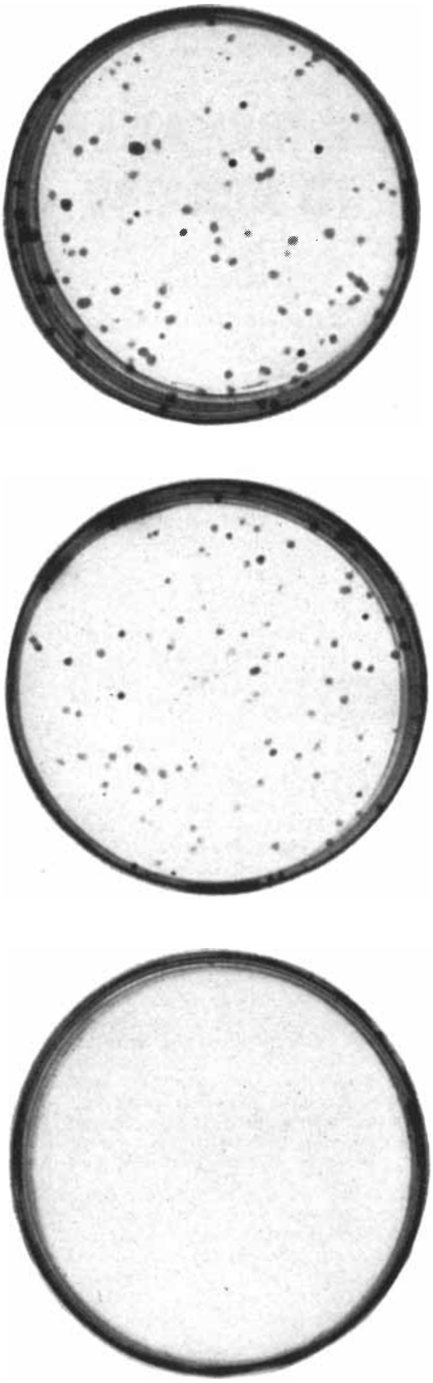
ity of mammalian cells to temperature is in sharp contrast to the behavior of bacteria; many of them will grow, though very slowly, even at temperatures as low as 32 degrees F.

In the same way we can measure the effects of various other agents besides cold. For example, if we prepare an antiserum (blood serum containing antibodies) and put a certain amount of it in a dish in which we have plated 100 single cells, the toxic effect of the antibodies is measured by the number of cells that fail to produce colonies. Similarly we can assay the inhibiting effects of measured doses of radiation, viruses and so on.

This sort of test provides a means of exploring genetic differences between cells, and some work along that line has already been done in our laboratory. The human HeLa (cancer) cells on which we performed our first experiments produced colonies of several distinct forms. We suspected that these represented different genetic strains of the HeLa type of cell. Tests of their responses to doses of human serum (as well as their differing food requirements) have confirmed this conjecture. In a medium containing a 5 per cent concentration of human serum, one strain yields colonies from single cells with 100 per cent efficiency while another produces no colonies at all. Cells of the two strains continue to show this contrast in behavior when tested even after both have been grown in the same medium for more than 100 generations, so the difference must be hereditary.

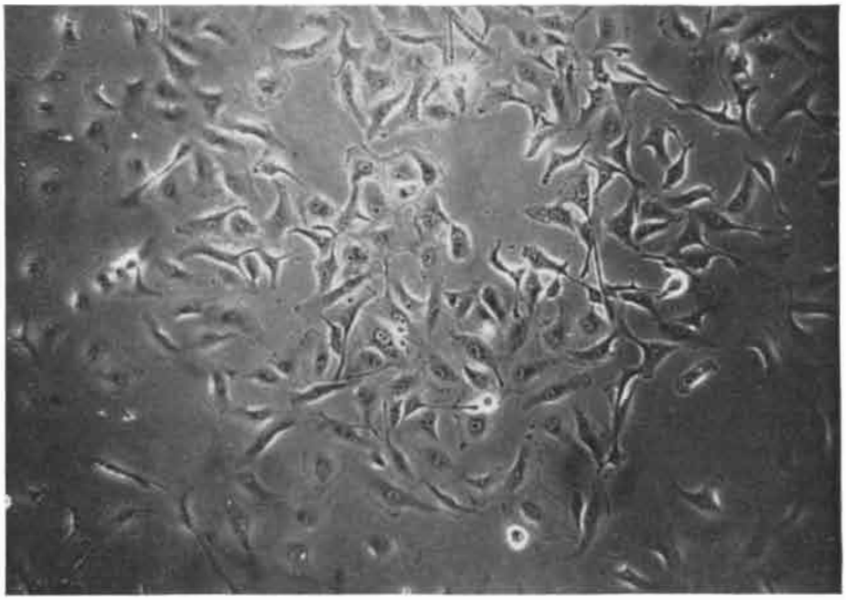
When we began to grow mammalian cells on glass, the first examinations of them under the microscope disclosed a striking fact. They tended to assume one or the other of two sharply contrasting forms. Here are two human cells of different types. Before being deposited on the glass, they are both spherical, indistinguishable in shape. Yet when they grow on glass, one produces a colony of closely packed, regular-shaped cells (arranged like the epithelial cells in a layer of skin), while the other forms stretched-out, spindle-shaped cells which move about and have a fibrous character (*i.e.*, they resemble cells of the type called fibroblasts). Presumably the stretching of cells into the fibrous shape is due to some interaction between the cell membranes and the glass. We were interested to find out whether the tendency to stretch out on glass depended on the heredity of the cells or on their environment (that is, on the nutrients supplied). Experimenting with different nutrient

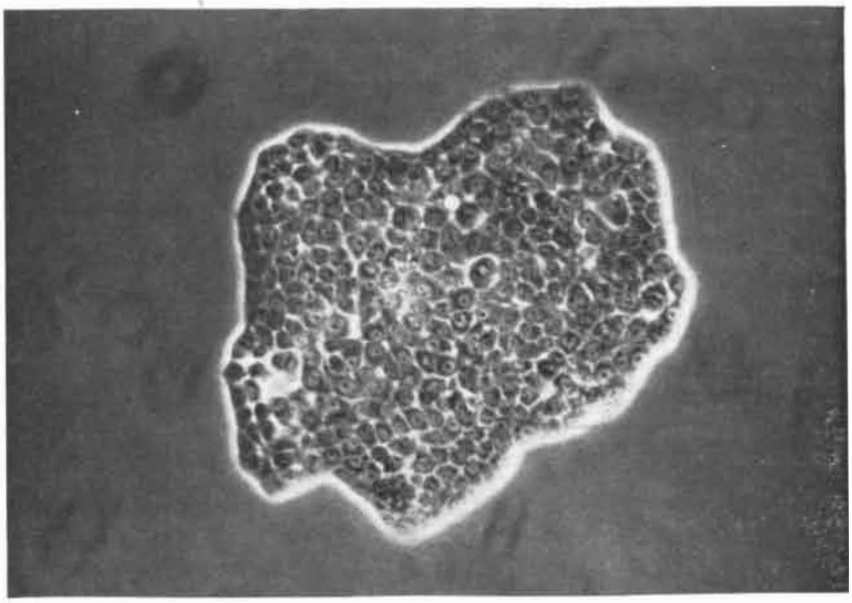


ANTISERUM STRENGTH is measured by means of the plating technique. The amount of antibody against tissue cells is proportional to the number of cells the antiserum can prevent from growing. Each of the plates shown here contained nutrient solution, but .1 per cent antiserum was added to the second plate and .4 per cent antiserum was added to the third. Of 100 cells plated on each, all formed colonies on the first two, but none grew on the third. Evidently the minimum concentration of antiserum which can prevent growth is between .1 per cent and .4 per cent. The exact figure can be determined by repeating the experiments with intermediate concentrations of antiserum. The colonies pictured are growing in nutrient solution without feeder cells.

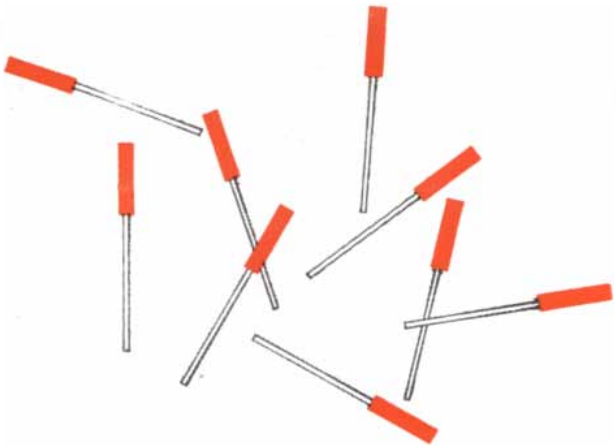
media, we found that genetic and environmental factors both seemed capable of influencing the form that the cells would take. An embryo extract, which presumably contains factors that cause differentiation of cells in the body, favored the multiplication of cells of the fibroblastic type. We used the selective action of the extract to identify and isolate cells of the epithelial and of the fibroblastic types. Both types bred true to form on glass through more than 20 generations. But we also found that by changing the nutrient medium (*e.g.*, increasing the concentration of human serum in the medium to more than 10 per cent), we could make cells of the epithelial type stretch out and begin to resemble the fibroblastic forms. This change could be reversed by changing the medium. We conclude that the environment can, in certain cases at least, greatly modify the expression of a cell's hereditary potentialities.

These studies appear to justify the hope that the ability to culture individual mammalian cells has now put biologists in a position to learn a great deal more about the anatomy, chemistry and behavior of the cells that form a human being.





SERUM MAKES THE DIFFERENCE in the appearance of these HeLa cells. The cells are all of the same strain, but the colony at top was grown in a fluid containing human blood serum while the colony below was grown in a fluid supplemented with bovine blood serum.



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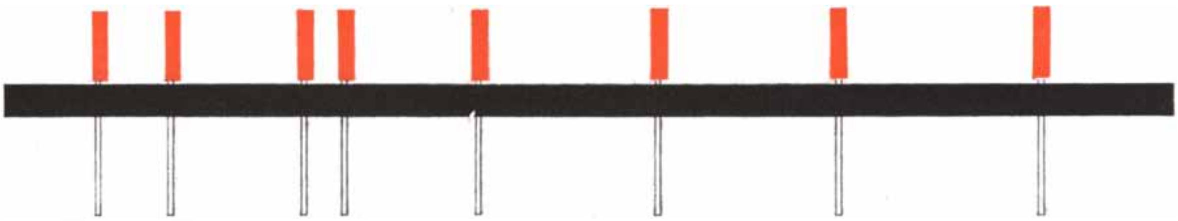

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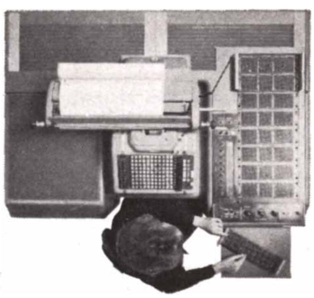

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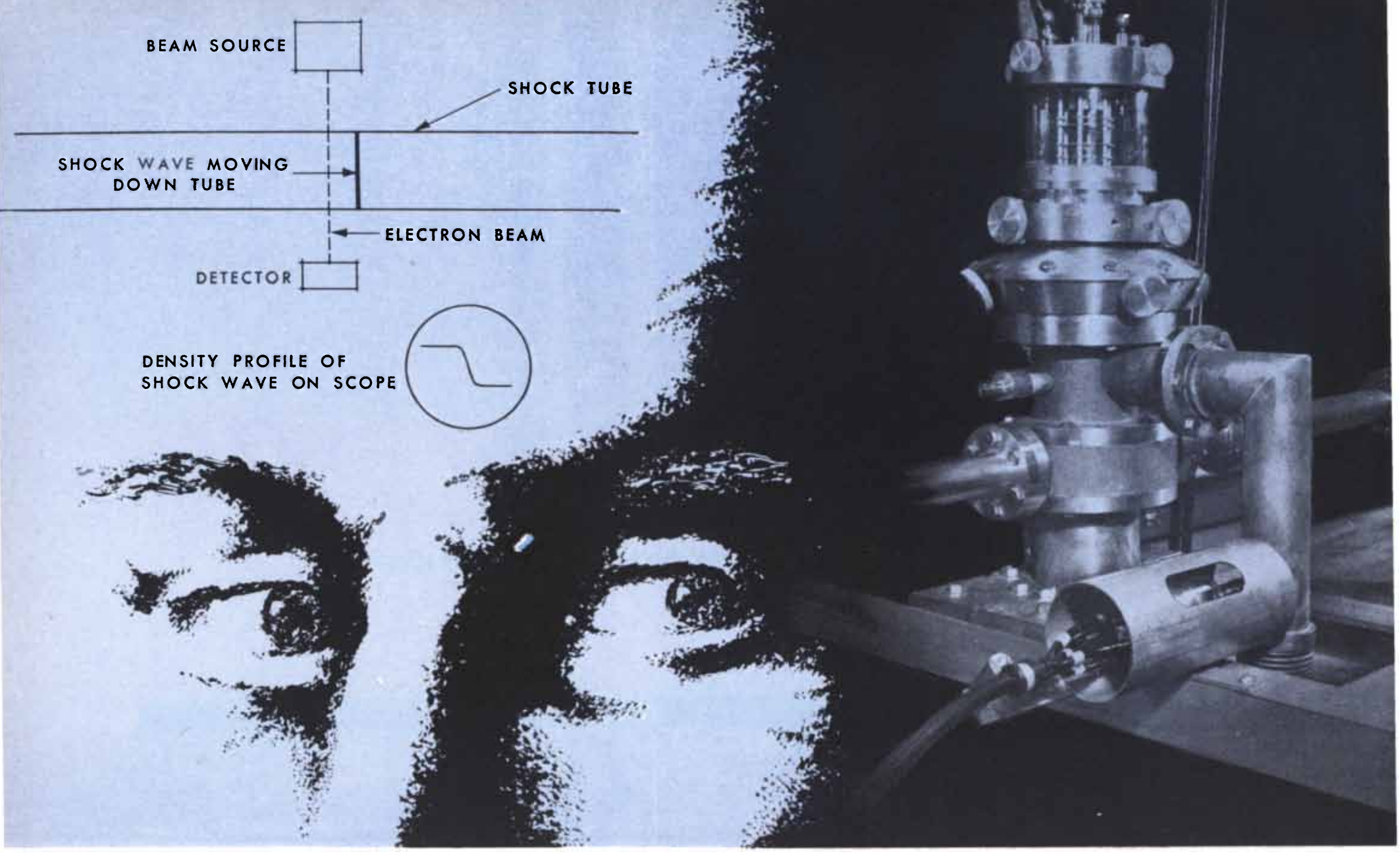

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Schizophrenia and Culture

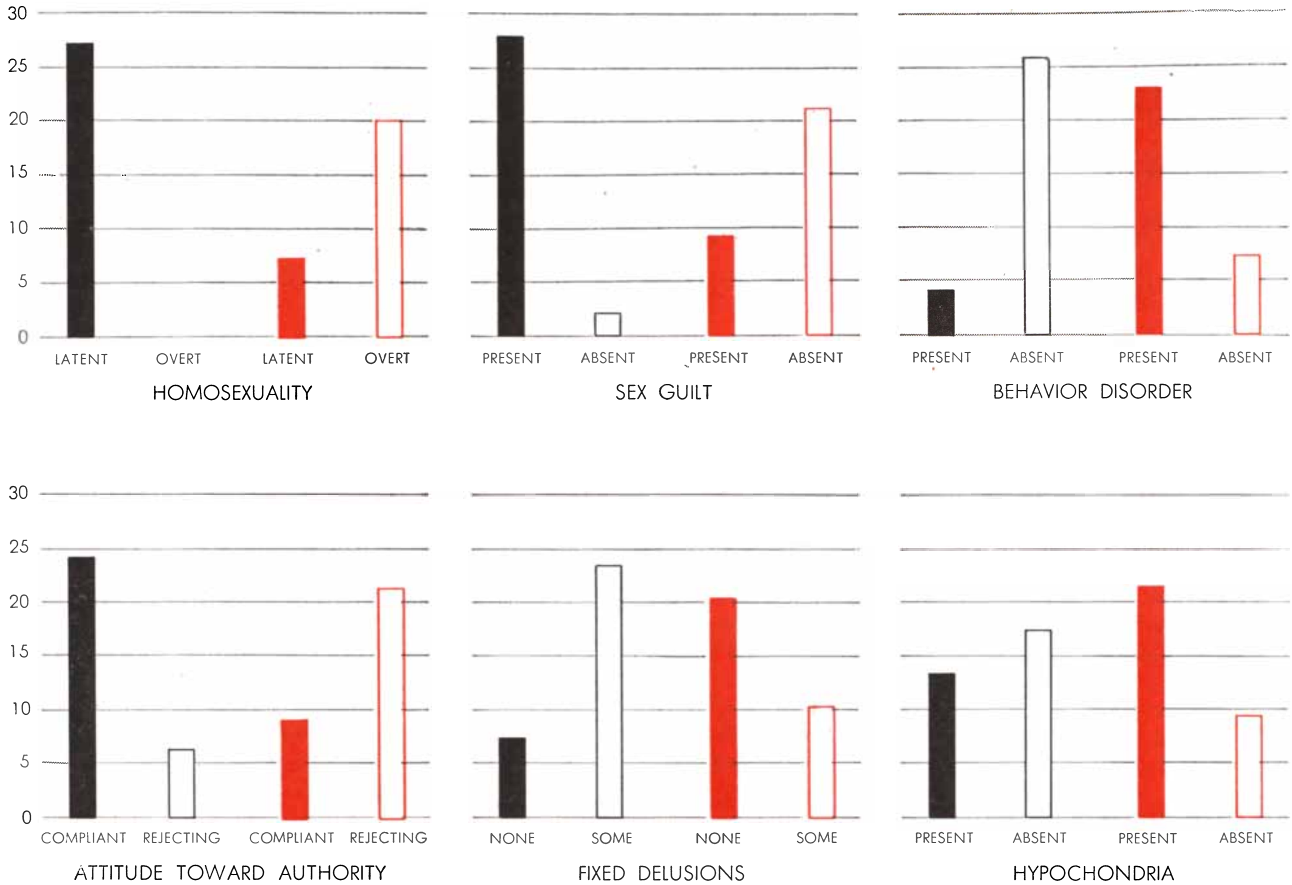
Schizophrenia is not one disease but many. It varies particularly with the cultural background of the individual. An account of its variation between two cultural groups, one Irish and one Italian

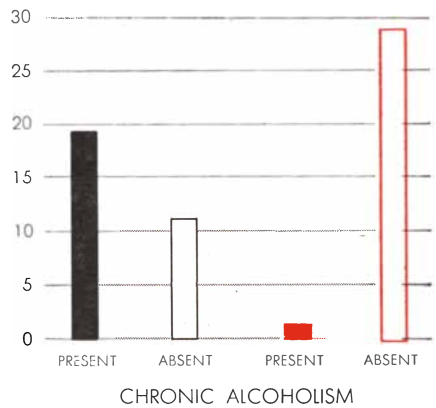
by Marvin K. Opler

Schizophrenia, the late psychiatrist Harry Stack Sullivan once observed, is "not a disease but a way of life." It was a profound remark. No single set of symptoms can describe the mental state called schizophrenia, nor can it be traced to any one specific cause. For a century all efforts to understand or treat the derangement as simply the breakdown of a diseased mind have failed. Schizophrenia takes many forms, bears the marks of social as well as individual disorders and is far too common to be attributed merely to private or individual aberrations. We must look beyond the individual to the outside forces that contribute to his flight into a schizophrenic "way of life."

It was the great Swiss psychiatrist Paul Eugen Bleuler who first urged this point of view and raised the hope that these psychoses might be curable. In 1911, in his classic work called *Dementia Praecox*, or *Group of the Schizophrenias* (the term schizophrenia, incidentally, was coined by Bleuler), he not only distinguished clearly between various kinds of schizophrenia but also focused attention on the fact that environmental influences—"external circum-

The pattern of schizophrenia in Irish males tends to be set by a dominating mother and the severe repression of emotions





ATTRIBUTES of 30 Irish (*black bars*) and 30 Italian (*colored bars*) male schizophrenics are compared. The scale on each chart indicates the number of patients with that attribute.

stances"—must play a major part in shaping the development of an individual's psychological derangement. If so, it should be possible, by changing the external circumstances, to arrest this development or divert the individual's psychological drives into healthier channels.

The preventive approach was pursued by the late Adolf Meyer, of the Henry Phipps Clinic of the Johns Hopkins Hospital, who popularized the term "mental hygiene." Like Bleuler, Meyer was impressed with the importance of environmental factors and saw distinct differences in the development of various schizophrenic disorders. He constructed a comprehensive view of mental illness as the product of biological, psychological and environmental influences.

It can fairly be said that we owe the origins of what understanding we have about schizophrenia mainly to Bleuler, Meyer and Sigmund Freud. They gave definition to its various types, meaning to its various symptoms and rationality to theories about its causes. Yet despite their emphasis on the background or social factors, studies of schizophrenia still seem focused too closely on the individual. There is evident need for examining it in a larger frame—to look at it in terms of populations or cultures. It should certainly be fruitful to study the schizophrenias specifically in a social context: how prevalent they are and what forms they take in particular cultures or societies. In short, what is needed is an approach combining the viewpoints of psychiatry and anthropology.

Actually Bleuler and Meyer provided leads for this kind of inquiry. Bleuler noted differences in schizophrenic "reactions" among peoples in Western Europe. Meyer's work inspired the first epidemiological study of mental illness in an urban community; it was carried out in a district of Baltimore. Within the past decade such studies have been renewed on a more massive scale. For example, the World Health Organization commissioned a British psychiatrist, J. C. Carothers, to survey mental illness among the peoples of Africa; in his findings, published in 1953, he reported that the patterns of mental illness varied considerably in the different regions of Africa. Last year I published the results of my own survey of the distribution of various types of mental illness among the peoples of the world in a book called *Culture, Psychiatry and Human Values.*

Beyond question intensive study of the epidemiology of mental illnesses could yield valuable information for the

understanding of these disorders. There is a long history of fruitful results from this strategy—the public health attack—in the fields of organic disease. It has been applied to tuberculosis, measles, diphtheria, pneumonia, scarlet fever, goiter, leprosy, pernicious anemia, arthritis, diabetes, high blood pressure, heart disease, cancer, alcoholism and various other illnesses. From such investigations have come many enlightening facts (*e.g.*, on the transmission of communicable diseases). They have shown that each disease is apt to have different rates in different ethnic or cultural groups: for example, certain forms of diabetes show a high incidence among Irish, Italian and Jewish males and low rates in some other groups. The disease may be rare in certain groups of first-generation immigrants to the U. S. and increase in the second generation.

Now much the same picture emerges from studies of mental illnesses, so far as these have gone. The psychoses and psychoneuroses are known to vary in rate and in type among different peoples. But what is needed is more information on the cultural factors that underlie these variations—on the stresses in family relations, modes of living and traditions which seem responsible for the differences in mental illness patterns. I have been interested in these questions for a number of years. A study of schizophrenic patients from Alaska at the Morningside Hospital in Portland, Ore., showed distinct differences between the Eskimo, Aleut, Indian and white patients. Three years ago I started an intensive investigation of schizophrenias among certain groups in New York City—Irish, Italian, Hungarian, German, Czech, Slovak, Puerto Rican and old American. What follows is a summary of our comparative analysis of two groups: Irish and Italian male schizophrenics.

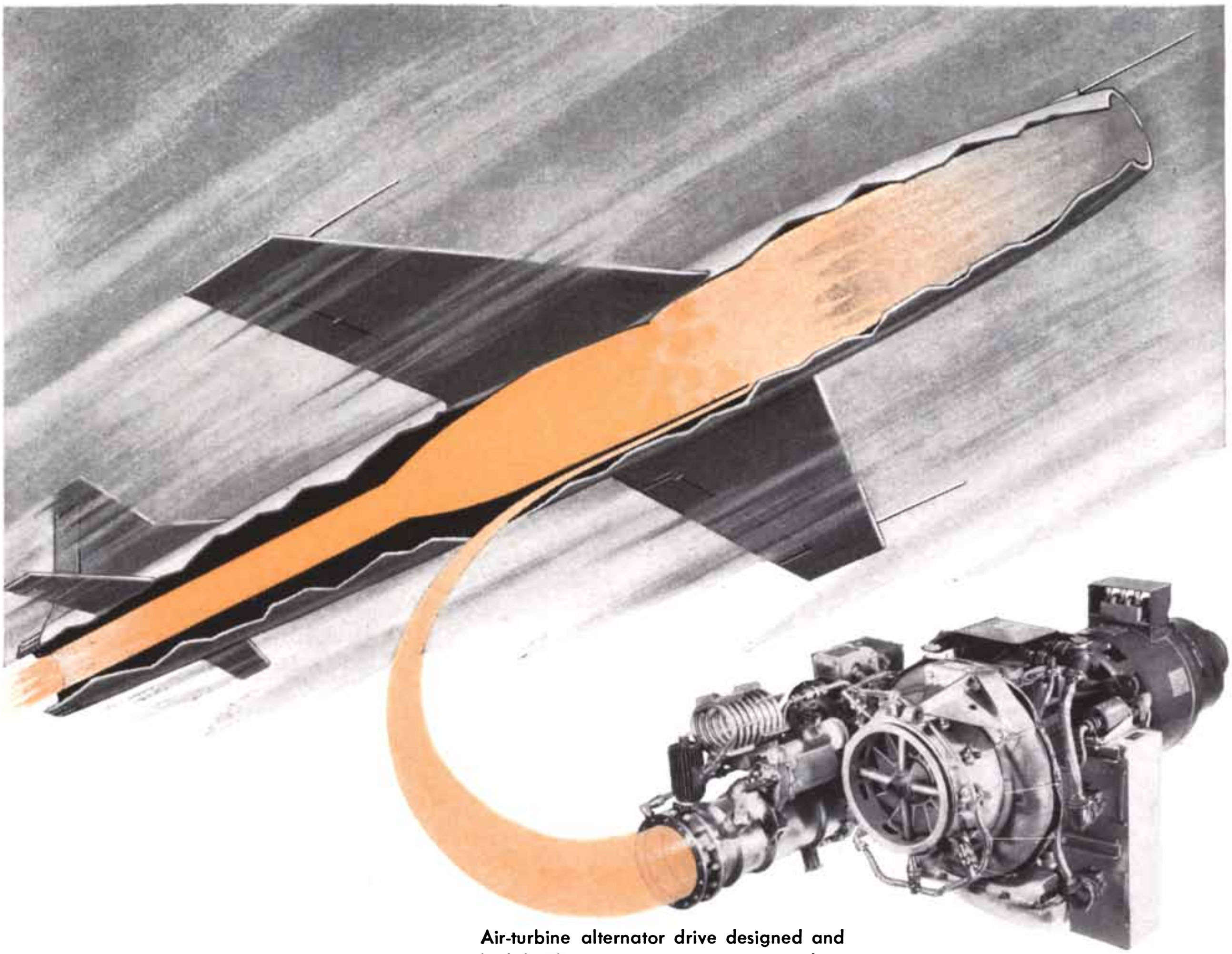
The subjects of our study were patients from New York City who were hospitalized in the Franklin D. Roosevelt Veterans Administration Hospital at Montrose, up the Hudson River. We found 30 Irish and 30 Italian patients, all definitely diagnosed as schizophrenic, who were capable of being fully interviewed and examined with psychological tests. Fortunately it turned out that the two groups matched almost exactly on many counts: they had about the same mean age (just over 30), education (10th grade), I.Q. (around 106), length of hospitalization (five years), economic level (low) and marital status (most of the men in both groups were unmarried). All were either immigrants or the sons or grandsons of immigrants from the old country, and they were even homogeneous in these origins: all the Irish families came originally from the "southwest" counties of Ireland, and all but one of the Italian from southern Italy or Sicily. (The lone North Italian, interestingly enough, proved to be significantly different from the South Italians in personality and symptoms.)

Every individual in each group was examined intensively by many available means. I studied their family backgrounds, their medical and psychiatric histories, the records of their behavior in the hospital and all the information that could be elicited from the patients themselves in interviews. Independently, Jerome L. Singer and his staff of clinical psychologists in the hospital examined each patient with a battery of 13 psychological tests (including the Rorschach and other well-known instruments). We then compared our results for the two groups.

In poorer Irish families the mother is apt to treat her sons as "forever boys and burdens"

Before studying the patients themselves, I had made field surveys of Irish and Italian family life in the section of New York City from which they came. The families studied ranged from well-adjusted to sorely troubled. Nevertheless, each ethnic group showed a clear and consistent pattern. The Irish family tends to be dominated by the mother; the father is often a weak and shadowy figure. The mother, assuming most of the major responsibilities, may treat her sons as "forever boys and burdens." In the Irish home active expression of emotions is frowned upon; sexual feelings are clouded with conceptions of sin. All this is reflected in the personality of the male offspring. The Irish male is apt to be quiet, repressed, shy or fearful of women and, as his literature attests, given to fantasy as an outlet for his emotions.

The Italian home is an almost total contrast. The dominant figure is the father. He rules the family with a sometimes benevolent, sometimes rough, hand. Emotions and passions are allowed



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free expression. Little or no sin or guilt is attached to sex. As a result the Italian male is proverbially excitable, given to acting out his emotions and sometimes hostile to his father and older brothers (to whom the father may delegate authority over him).

This brief summary of major differences between Irish and Italian family organization and attitudes is of course greatly simplified and indicates only the dominant trends. Not all Irish families fit the description given above, nor all Italian. But the tendencies are quite clear, and we should expect to find them reflected in personality contrasts at normal and aberrant levels. Just as families in each group cover a continuum from the harmonious to the disorganized, so the personality structure of their members ranges over a continuum from healthy to very sick. The stresses characteristic of a culture are present even in well-adjusted families. Extreme exaggeration of these stresses may lead to characteristic mental disorders among individuals of the group. And if we have correctly analyzed the elements of stress in Irish and Italian family life, we should be able to predict what shapes their schizophrenias are likely to take.

Our examinations of the 30 Irish and 30 Italian patients demonstrated that they did indeed run true to predictions. We adopted a set of criteria to show the basic elements in the contrasting schizophrenias of the two groups. On each criterion the results bore out our analysis [*see charts on page 104*]. Let us consider them one at a time.

Most schizophrenics have a homosexual bent or conflict. This was fully confirmed by the histories and psychological tests of our two groups of patients: 27 of the 30 in each group revealed homosexual tendencies. But there was a sharp contrast in expression of the tendency. In the 27 Irish patients the homosexuality was latent but repressed, whereas 20 of the 27 Italians had become overt homosexuals. The underlying factors in both cases are clear. The Italians had rejected a male role out of hostility to their overbearing fathers and elder brothers. Italian men, no less than Irish men, take pride in masculinity; indeed, they are, if anything, more masculine in behavior. But they are also readier to act on sexual impulses, and when they lose their sense of sexual identification in schizophrenic illness, they do not shrink from overt homosexual behavior. Irish men, on the other hand, flee from their identity as males through fear of the mother rather than hostility to the father. All of our Irish schizophrenic patients were either pallidly asexual or latently homosexual. Most of them avoided females. Their homosexuality was repressed because sexuality in general is inhibited in the Irish culture. But it emerged in their fantasies. Indeed, some misidentified themselves as women: one patient had the delusion that the front of his body was covered by an "apron" which bled periodically.

The pattern of schizophrenia in Italian males tends to be set by a dominating father

The second difference between the two groups also pertains to the sexual area and is related in part to the first. Nearly all the Irish schizophrenics tormented themselves with preoccupations of guilt about sex, whereas most of the Italians had no trace of such Puritanism.

Another expression of the contrast in patterns was the record of the patients' general behavior. Twenty-three of the 30 Italians had a history of repeated aberrations of behavior—temper outbursts, assaults, destruction of property, attempts at suicide and so on. In the hospital they tended to be difficult to manage. In contrast, 26 of the 30 Irish patients had never been in any trouble of this kind. In the hospital they were passive, compliant, withdrawn. These were the quiet, anxious men, fearful of anything which might separate them from the protection of the hospital. The picture was further confirmed by separate analyses of the attitudes of the respective groups toward authority. A large majority of the Italians were rebellious against authority; most of the Irishmen expressed compliant attitudes.

One of the most significant manifestations of the psychological difference between the two groups had to do with the tendency to develop and hold schizophrenic delusions. Three quarters of the Irish patients had elaborate and fixed delusions—paranoid conceptions of remarkable powers or persecution. One of them kept repeating an account of the

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death of his father in a gory accident in front of their house, for which the patient blamed and cursed his mother. Actually the father had died in a hospital of a common ailment at a ripe old age. That Irish men would be inclined to delusions in schizophrenia was predictable on the basis of their pattern of anxiety, sexual repression, feelings of guilt and tendency to find outlets in fantasy. The Italians, on the other hand, showed far less disposition to seek this form of escape. Two thirds of them gave no evidence of any delusions whatever. Instead, their reaction to the stress of their problems and to blows to their self-esteem found expression in violent swings of mood, excitements, destructive outbursts, overtalkativeness, hysterical laughter and curious mannerisms. In short, their defenses took the form of action and direct expression of feelings rather than the cloak of fantasy.

On the basis of Italians' less inhibited interest in bodily functions, it could be predicted that the Italian patients would be more prone than the Irish to hypochondria. The analysis proved that this was indeed the case: more than two thirds of this group were given to bodily preoccupations and complaints of imaginary disorders, whereas a majority of the Irish patients were not.

Finally, it is well known that Irish men are prone to seek escape in alcohol, and our sample documented this. Two thirds of the Irish patients had been alcoholics. Contrarily, although the Italians liked to drink, only one of the group of 30 had ever been addicted to alcohol.

At a more basic level, we compared the two groups in emotional attitude, as shaped by the family structure, and in the typical form of expression of their emotions. We expected the Irish patients, raised in homes strongly dominated by the mother, to be ridden by anxiety, tinged with fear and hate. This was confirmed by psychological analysis of the patients, and in two thirds of the cases the patients' anxiety was directed primarily toward females. Three of the Irish patients, however, came from families in which the father was the central figure, and in these three cases, significantly enough, the whole pattern of their illness resembled the Italian model rather than the Irish.

In the Italian pattern, of course, hostility was more apparent and directed primarily toward males. In practically all the cases there was a strong repulsion from the father, an elder brother or a substitute male figure of authority. Coupled with this was poor emotional control, which had often been fostered by an indulgent and possibly seductive mother.

When it comes to expression of emotions, we see a sharp contrast between the two groups: one channeling its emotional drives into poorly controlled, impulsive action, the other into fantasies or delusions. Italians, whose culture sanctions expression "from the heart," act out their feelings, characteristically in the form of bodily action. The Irish, at the other extreme, tend to give expression to their emotions vicariously in fantasy: their rich fantasy life is their most famous and most endearing trait. These opposite trends were exhibited, in highly exaggerated form, by our two samples of schizophrenic patients.

Taking all the symptoms together, we can separate the Irish and Italian schizophrenias into two distinct patterns. We see the Irish patient fearful of females, low in self-esteem, tortured by feelings of guilt and inadequacy, sunk in paranoid delusions. We see the Italian schizophrenic, on the other hand, hostile to male figures, overtly homosexual, extremely impulsive and excitable, subject to moods of depression or uncontrolled elation, sometimes assaultive and destructive. Each of these patterns bears the imprint of the underlying family experience and pattern of stress.

This sort of research cannot fail to improve our understanding and treatment of schizophrenic disorders, particularly if it is supplemented by studies of the organic or physiological effects accompanying each type of personality imbalance. Furthermore, the same approach—social psychiatry—could be applied with profit to investigations of other mental disorders besides the schizophrenias.

Irish patients were often alcoholics

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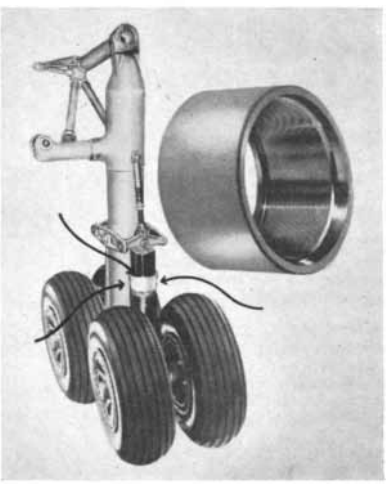

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THE EDIBLE SNAIL

The French now eat more than 8,000 tons of snails in a year. The cultivation and shipping of these succulent creatures are a triumph over their delicate adjustment to their environment

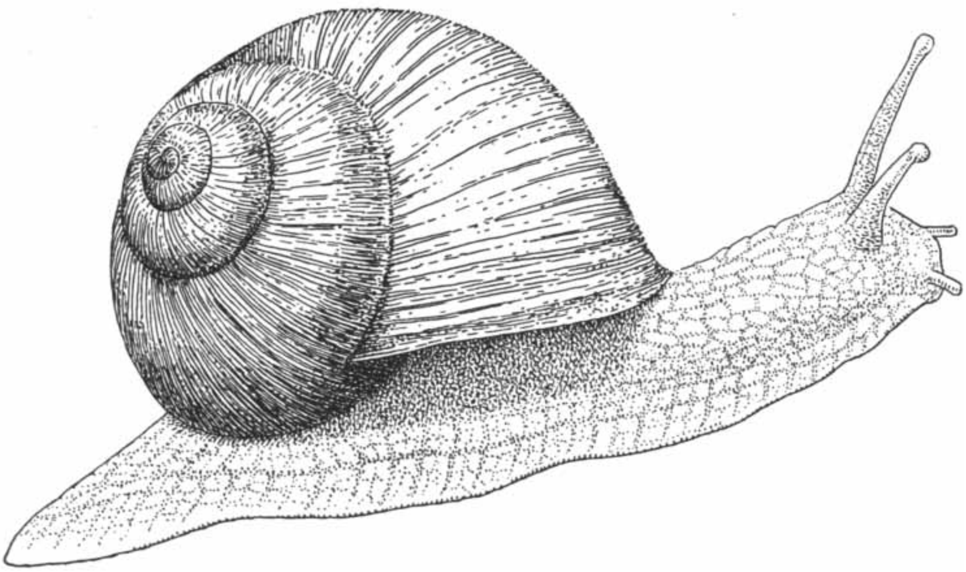
by Jean Cadart

The snail is an ancient food of mankind. Shells strewn in Paleolithic camp sites suggest that some Stone Age groups lived almost entirely on snails. The Greeks relished them, and Aristotle carefully described their anatomy. They were cultivated by the Romans, and by monks and nuns in medieval times. Somehow the snail later fell into disrepute as a dish wanting in flavor and digestibility. But it has long been appreciated by French gastronomes, and during World War II its virtues as a food were rediscovered by the French people. Many families made two or more meals a week out of snails as a nice substitute for the meat course. Since the war the French have taken to eating more and more of the creatures. In 1952 they consumed 600 million snails—8,800 tons. The snail trade is now a substantial industry in France.

Naturally this brings its problems. The snail's physiology is as delicate as its flavor. The slightest mishandling of the animal *en route* to the table robs it of its prime condition. And as is always the case, mass production and consumption lengthen the distance, in time and space, between the producer and the consumer. The snail is at its best in the spring, but the demand reaches its peak in the winter: during the Christmas-New Year holidays the Paris area alone consumes 200 tons. Thus the details of the snail's biology have become a matter of commercial importance. Successful production and handling of the animal on a large scale call for a thorough scientific knowledge of its characteristics and habits.

It is from this practical point of view that I have pursued my extensive studies of the snail and amassed the information contained in my book, *Les Escargots.* Ordinarily the study of an animal to solve commercial problems would be very different from the approach of a zoologist. But not in this case. It has been necessary to learn a great deal about the snail's anatomy and physiology, to observe how it lives in the "wild" state and to perform well-controlled experiments. In my studies of these matters I have had the benefit of advice from such experts as Gilbert Ranson, assistant director of the National Museum of Natural History in Paris.

Everyone is more or less familiar with the general features of the snail, particularly its spiral shell and its retractable abdominal foot (from which comes the name gastropod, although the animal's belly is not really its stomach). Of the shell we need say no more here



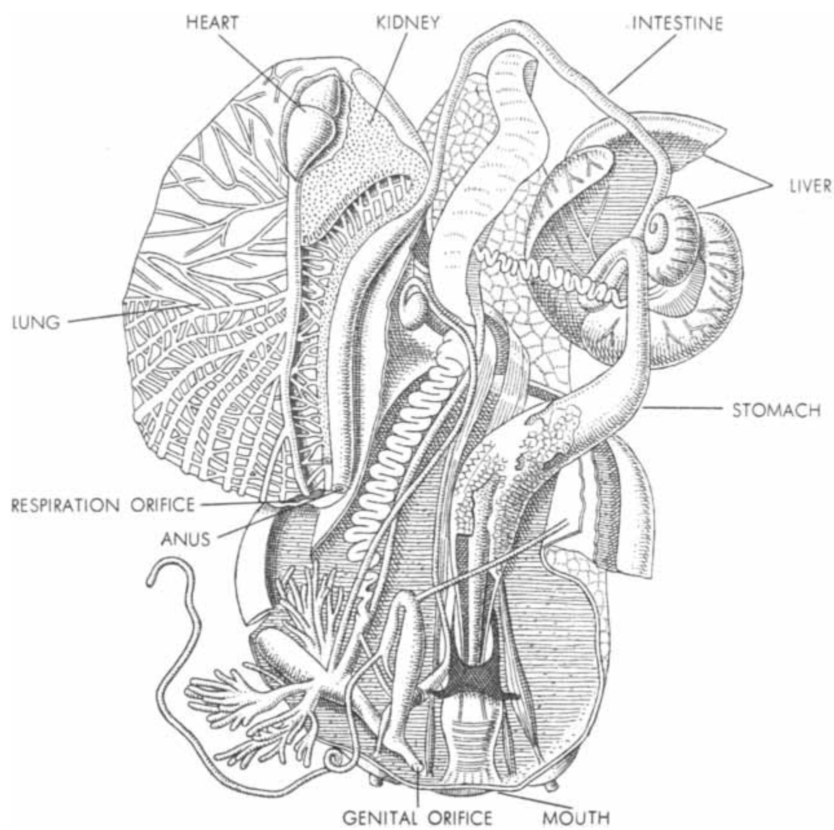
BURGUNDY SNAIL (*Helix pomatia*), a favorite among French connoisseurs, is enlarged 1.5 times. Though the two long tentacles on its head bear eyes, the snail is almost blind. The shorter tentacles, however, provide the animal with an exquisite sense of touch.

than that it is customary to cook and serve the snail in its own residence; nowadays the shell can be vitrified and thus made washable and reusable. The foot is an altogether remarkable affair. It is so strong that a snail can pull a toy wagon loaded with 200 times its own weight—the equivalent of a 10-pound baby hauling an automobile! At the front of this "foot" is the head, with two long tentacles that carry tiny eyes and two short ones that serve as extremely sensitive organs of touch. Also in the foot are the genital orifice, the respiratory orifice and the anus. For its size the animal has a powerful breathing apparatus: it can make the flame of a candle flicker. One species, the Burgundy snail, has 25,600 pseudoteeth lining its tongue, and it will gnaw valiantly at the wooden bars of a cage.

From the gastronomical point of view the richest and most delectable part of the snail is the upper portion, coiled within the spiral of the shell. Here resides the animal's visceral mass. It contains the tiny heart, lung, genital gland, kidney, intestine, etc., but most of its bulk is made up of the liver, the snail's digestive organ. It is to the liver, particularly its glycogen (starch), that the snail largely owes its savor, easy digestibility and nutritive value. Ounce for ounce the snail's visceral mass contains more protein, fat and mineral salts than do beef or fish. The delicate flavor of the snail is accounted for mainly by the liver and the genital gland.

The life of this land-dwelling mollusk is primarily governed by moisture. Its extended foot has absolutely no way of controlling the intake or loss of water. Too much dampness or too much dryness in its environment, a high wind that increases evaporation—these may be fatal to the creature. Nor does it like the cold. In the autumn the snail retires within its shell and goes to sleep for several months. For this hibernation the animal closes up its shell with a bottom lid made of a secreted material. The two common edible species do this in different ways. The Burgundy snail (*Helix pomatia*) forms a hard covering which is calcareous, like an eggshell; the petit-gris (*Helix aspersa*) covers the opening with a thin, translucent veil.

To become acquainted with the creature's habits, let us begin with a spring morning in the life of a Burgundy snail. This morning the snail, aroused



ANATOMY OF THE SNAIL is unfolded in this drawing of its soft parts from above. The organs shown constitute the visceral mass, which is coiled within the shell of the snail.

Staff Scientist Dr. J. W. Muehlner (center) discusses an advanced PDM telemetering system for missile application with K. T. Larkin (left), Telecommunications Department manager, and J. R. Dawley, Telecommunications Systems Section head.

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CALIFORNIA

SNAIL PARK provides snails with shade, moisture and food during the summer. In the fall the snails burrow into the ground and close their shells with a lid. At this point, when they are most edible, the snail farmer harvests them for shipping to the market.

by the mild air and the coming of the season of food abundance, emerges from its winter sleep. Advancing by a series of slow undulations of its foot at the snail's pace of two and a half inches per minute, the mollusk ventures forth in search of the tender herbage it likes. It creeps over the dewy soil, soaking up a respectable amount of water. If, during its excursion, a wind springs up or the temperature falls, the snail will retreat to a sheltered spot and veil itself again temporarily. Until favorable conditions return, it passes the time in slumber—sleep seems to be its privileged state of life. Its excursions and meals are sharply circumscribed by the weather and the time of day.

Above all, it is ruled by water. It must maintain the percentage of water in its tissues at a certain level, and yet it cannot control either its intake or its loss, except by sealing itself up with a veil. The snail is extraordinarily sensitive to humidity—how sensitive I was able to learn by an experiment. I put some snails in a sealed, airtight tank. After a while the tank became humid with water evaporated from the animals' bodies. Within a few hours the snails died. But when I performed the experiment with calcium chloride in the tank to absorb the exuded water, the snails survived.

It is on spring mornings after a rain, when the snails go forth to find food and the grass is still short enough to expose them to view, that snail farmers collect their stock. They incarcerate their captives from the wild in enclosed "parks," where the animals are provided with food and shade. In due time, when the snails have grown fat, they must be shipped to market. How is this to be done?

The first method that comes to mind is to can them, like fish or other meat. This procedure commends itself by its convenience, cleanliness and safety. But canning may rob the snail of some of the qualities that endear it to a connoisseur. And so at least part of the crop must be brought to market alive and fresh. It is here that we must call upon our knowledge of the snail's physiology. How shall we prevent it from dying because of incorrect humidity conditions or from wasting away during the long fast of its journey?

If we transported the creatures in closed boxes we would kill them, as their tenderness to humidity in our experiment demonstrated. Therefore it is imperative to ventilate their travel compartments: they are shipped in windowed cagelets so that the moisture the snails give off can escape. Upon arrival in the market they should be kept in a chamber with ventilators which can be turned on when hygrometer readings show that the room is too humid.

Now we must also arrange to prevent emaciation of the snails during this foodless period. Here we may think of the engine of a car. If we are looking for the most economical running conditions for a car, we shall find them in the low-speed range. Similarly the snail will consume the least fuel at its low speeds. The problem becomes a matter of slowing down its metabolism. We know that the snail lives at a slow rate in winter, sleeping and conserving its body's reserves. Hence the solution of our problem is to keep it in a wintry environment—*i.e.*, refrigeration.

I have conducted a great many experiments in search of the conditions that will cause the snail to retire temporarily into its winter state. The appropriate temperature seems to depend on how long the animal is to be kept in the refrigerated room: the briefer the stay, the lower the temperature should be. Generally, a safe temperature would seem to be about 36 degrees Fahrenheit.

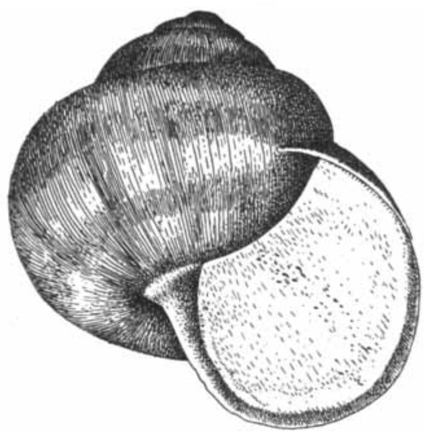
Ideally we wish to do something more than slow the animal's metabolism. We should like to make it seal itself up with the cover that it forms over the opening at the bottom of its shell in winter. In the case of the Burgundy snail this would accomplish two things. It would prevent the animal's loss of water, and it would free the snail's flesh of gritty lime—the substance which it uses to form the cover.

When winter comes, the Burgundy snail withdraws into its shell and lies on its back with the opening facing upward. It then secretes a mucus containing dissolved limestone. The lung inflates this to a hemispherical bubble which spreads, flattens and finally covers

the opening. Now the lime crystallizes and becomes a hard cover—called the operculum.

How could we induce this process artificially? The problem is complex. Experiments have shown that no single factor is decisive—temperature, humidity, accumulations of calcium salts in the snail's body, or whatever. As Ranson well says: "We do not know, in spite of all the research that has been done, what external and internal factors preside over this function in nature. At the coming of winter the snail stops itself up, after having buried itself. It is hard to reproduce exactly the progressive alterations of the environment—the changes in heat and light, for instance—that trigger the secretion of the snail's operculum."

Thus the problem of bringing snails to the table in all their delicacy—a problem seemingly trivial from the scientific point of view—leads us to a really profound question in biology. What complicated interaction of the environment and the snail's physiology causes the animal to produce this admirably efficient structure for assuring its survival when winter comes? What is the internal mechanism that carries out the construction of the operculum? Certain investigations suggest themselves. We can suppose, for example, that a system of hormonal secretions, triggered into action by the seasonal changes in the environment, may cause the animal to begin accumulating a supply of limestone and finally, at the appropriate time, to spend this material in building its operculum. This in itself promises a fascinating inquiry. We are drawn on irresistibly to further studies of the humble—and delectable—snail.



PLUG which closes the Burgundy snail during the winter is made of the particles of lime which during the summer are distributed throughout its body. When snails are harvested in winter they are free of lime.

MATHEMATICAL GAMES

The life and work of Sam Loyd, a mighty inventor of puzzles

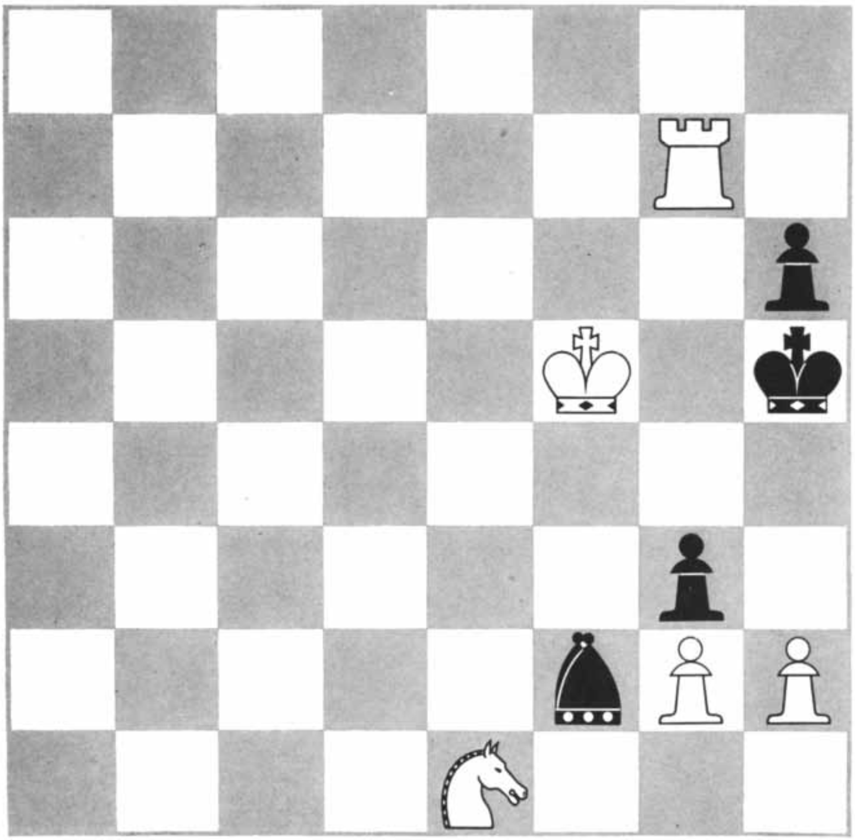
by Martin Gardner

The name Sam Loyd will not be familiar to most readers of this magazine, yet Loyd was an authentic American genius, and in his time something of a celebrity. For almost half a century, until his death in 1911, he was the nation's undisputed puzzle king. Thousands of superb puzzles, most of them mathematical, appeared under his name; many are still popular today.

Actually there were two Sam Loyds—father and son. When the elder Loyd died, the younger dropped the "Jr." from his name and continued his father's work, writing puzzle columns for magazines and newspapers, and issuing books and novelties from a dingy little office in Brooklyn. But the son, who died in 1934, did not possess the father's inventiveness; his books are little more than hastily assembled compilations of his father's work.

Loyd senior was born in Philadelphia in 1841 of (as he once put it) "wealthy but honest parents." In 1844 his father, a real estate operator, moved the family to New York, where Sam attended public school until he was 17. If he had gone to college he might well have become an outstanding mathematician or engineer. But Sam did not go to college. One reason was that he had learned to play chess.

For 10 years Loyd apparently did little except push chess pieces about on a chessboard. At that time chess was



A famous chess problem devised by Loyd: "Charles XII at Bender"

Project Engineer Robert J. Cantwell uses a system of gimbals to describe navigational problem in the analysis of a new system design.

Development Engineer J. Robert Holmes computes, with other systems reliability analysts, the operational worth of a bombing system.

Staff Engineer William Howard reviews gearing accuracy requirements of test equipment with electronic circuit designers.

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Circuit Development Group Leader Ralph Wolcott considers future changes in computer output unit for bombing-navigational systems.

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Development Engineer John Walsh discusses the use of a recording storage tube at IBM's Airborne Computer Laboratories, Owego, N. Y.

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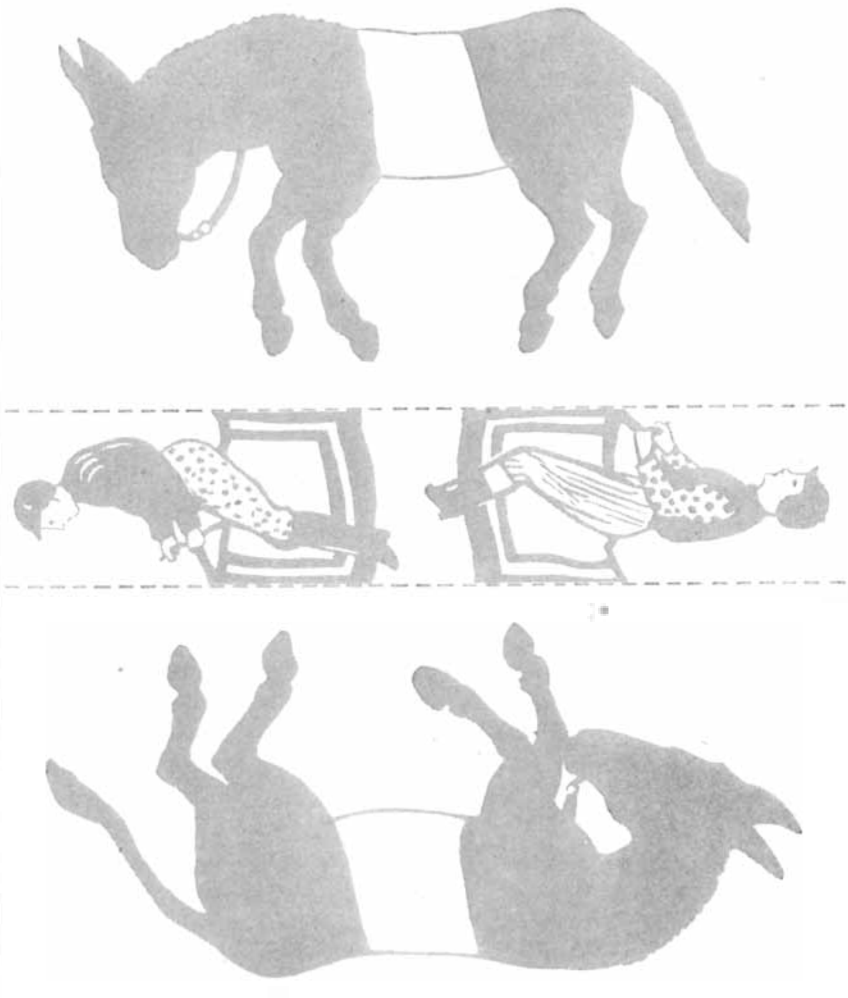

Loyd's puzzle of the two donkeys and the two jockeys

enormously popular; many newspapers carried chess columns featuring problems devised by readers. Loyd's first problem was published by a New York paper when he was 14. During the next five years his output of chess puzzles was so prodigious that he became known throughout the chess world. When he was 16 he was made problem editor of *Chess Monthly*. Later he edited several newspaper chess columns and contributed regularly, under various pseudonyms, to a score of others.

In 1877 and 1878 Loyd wrote a weekly chess page for *Scientific American Supplement*, beginning each article with an initial letter formed by the pieces of a chess problem. These columns comprised most of his book *Chess Strategy*, which he printed in 1878 on his own press in Elizabeth, N.J. Containing 500 of his choicest problems, this book is now much sought by collectors.

Loyd's most widely reprinted chess problem, composed when he was 18, illustrates the delightful way in which his posers were often dressed up with anecdotes. It seems that in 1713, when Charles XII of Sweden was besieged by the Turks at his camp in Bender, the king often passed the time by playing chess with one of his ministers. On one occasion, when the game reached the situation depicted on page 120, Charles (playing white) announced a checkmate in three moves. At that instant a bullet shattered the white knight. Charles studied the board again, smiled, and said he did not need the knight because he still had a mate in four moves. No sooner had he said this than a second bullet removed his pawn at king's rook 2. Unperturbed, Charles considered his position carefully and announced mate in five.

The story has a topper. Years later a German chess expert pointed out that if the first bullet had destroyed the white rook instead of the knight, Charles still would have had a mate in six. Chess-

Bill Erickson discusses MAGNETIC TAPE RECORDING

Most phenomena that can be depicted electrically can be recorded on magnetic tape. Long-known but relatively recently perfected, magnetic tape recording has won wide acceptance as a particularly valuable tool in data-handling and process control applications. The very nature and versatility of this tool, however, require the most mature judgment in its use, lest unwarranted enthusiasm lead to misapplications and incorrect results.

In the field of industrial control, magnetic tape recording has been used most effectively for the storage of electrical analog information in such processes as conveyor control for article sorting, machine tool and pattern control, dry and liquid food batch mixing, and so forth. In data-handling problems, it has served the engineer in speeding analyses of complex physical phenomena. In communications experiments, multi-channel tape units have provided the scientist with simulation of otherwise physically unrealizeable filters. In all these instances, the merit of magnetic tape recording lies in its ability to store electrical analog information and make it available for play-back, or re-run, as often as may be necessary.

Of the few methods available to "advance" or "retard" time, none is as practical as the use of magnetic tape. For instance, it is frequently overlooked that a tape recording can be considered as a variable delay line of considerable equivalent electrical length. Merely by varying the playback speed, or the relative position of the reproduce heads, or both, one line (or tape) can be used to delay a number of signals relative to each other, one signal relative to a number of others, or to some external source.

Despite this versatility there are definite limits of usefulness within which the application of tape recording should be confined. Such a limit is typified in the problem of signal "dropout." By this is meant the distortion, or even complete loss, of a signal caused by the presence of minute nodules in the tape itself. The occurrence of such imperfections is completely random and can be controlled only during production of the tape. And while significant progress has been made in recent years to improve the quality of tape, ultimate perfection has not yet been achieved.

In data-handling and process control fields, the use of magnetic tape recording is particularly well-suited to digital techniques where large quantities of information can be stored most economically in a minimum amount of space. In all applications where high-speed random access is not required, magnetic tape recording provides a relatively inexpensive and wholly suitable solution to the recurring information storage problem. Here signal dropout is virtually eliminated because the electrical impulses are of a pulse present-pulse omission presentation and are recorded at, or very near, the tape saturation level.

Wilbur Erickson, systems engineer, specializing in input-output equipment, discusses magnetic tape recording.

The use of magnetic tape recording is, at one and the same time, the prerogative and the responsibility of the systems engineer. His experience and ability to make intelligent use of this one of the many tools available to him, will define his stature as a systems man. The potential of magnetic tape recording in systems has barely been scratched, but the applications to which it can, and undoubtedly will, be put are as limitless as man's imagination to devise them.

By applying the latest proven techniques, our well-qualified staff at Daystrom Systems is prepared to take single responsibility of assembling and installing a system to meet your needs. We are currently compiling a file of new applications and papers on various parts of systems, both industrial and military. If you are interested in receiving the file and periodic additions, please write Dept. 12.

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playing readers may enjoy tackling this remarkable four-part problem.

The original version of Loyd's first commercially successful puzzle, drawn by himself in his late teens, is depicted on page 122. When the puzzle was cut along the black lines, its three rectangles could be arranged (without folding) so that the two jockeys rode the two donkeys. P. T. Barnum bought millions of these puzzles from Loyd, and distributed them as "P. T. Barnum's Trick Donkeys." It is said that the puzzle earned young Loyd $10,000 in a few weeks; it is popular to this day.

From the mathematical standpoint Loyd's most interesting creation is the famous "14-15" or "Boss" puzzle. This had a surprising revival eight years ago and can still be bought at the toy counters of most five-and-ten-cent stores. As shown in the illustration at left on this page, 15 numbered squares are free to slide about within a box. At the beginning of the puzzle the last two numbers are not in serial order. The problem is to slide the squares, without lifting them from the box, until all of them are in serial order, with the vacant space in the lower right-hand corner as before. In the 1870s the 14-15 puzzle had a tremendous vogue both here and abroad and numerous learned articles about it appeared in mathematical journals.

Loyd offered a prize of $1,000 for a correct solution of the puzzle. Thousands of people swore they had solved it, but no one could recall his moves well enough to record them and collect the prize. Loyd's offer was safe because the problem is not solvable. Of the more than 20 trillion possible arrangements of the squares, exactly half can be made by sliding the squares from the arrangement depicted here. The remaining positions, including the one sought, have a different "parity" (to use the language of permutation mathematics) and cannot be reached from any position possessing the opposite parity.

The game was sometimes played by placing the squares in the box at random, and then trying to slide them into serial order. The probability of succeeding is of course 1/2. A simple way to determine whether any arrangement B can be obtained from any arrangement A is to see how many "interchanges" (exchanging the positions of any two squares by removing them from the box and replacing them) are required to convert A to B. If this number is even, A and B have the same parity and either can be obtained from the other by sliding.

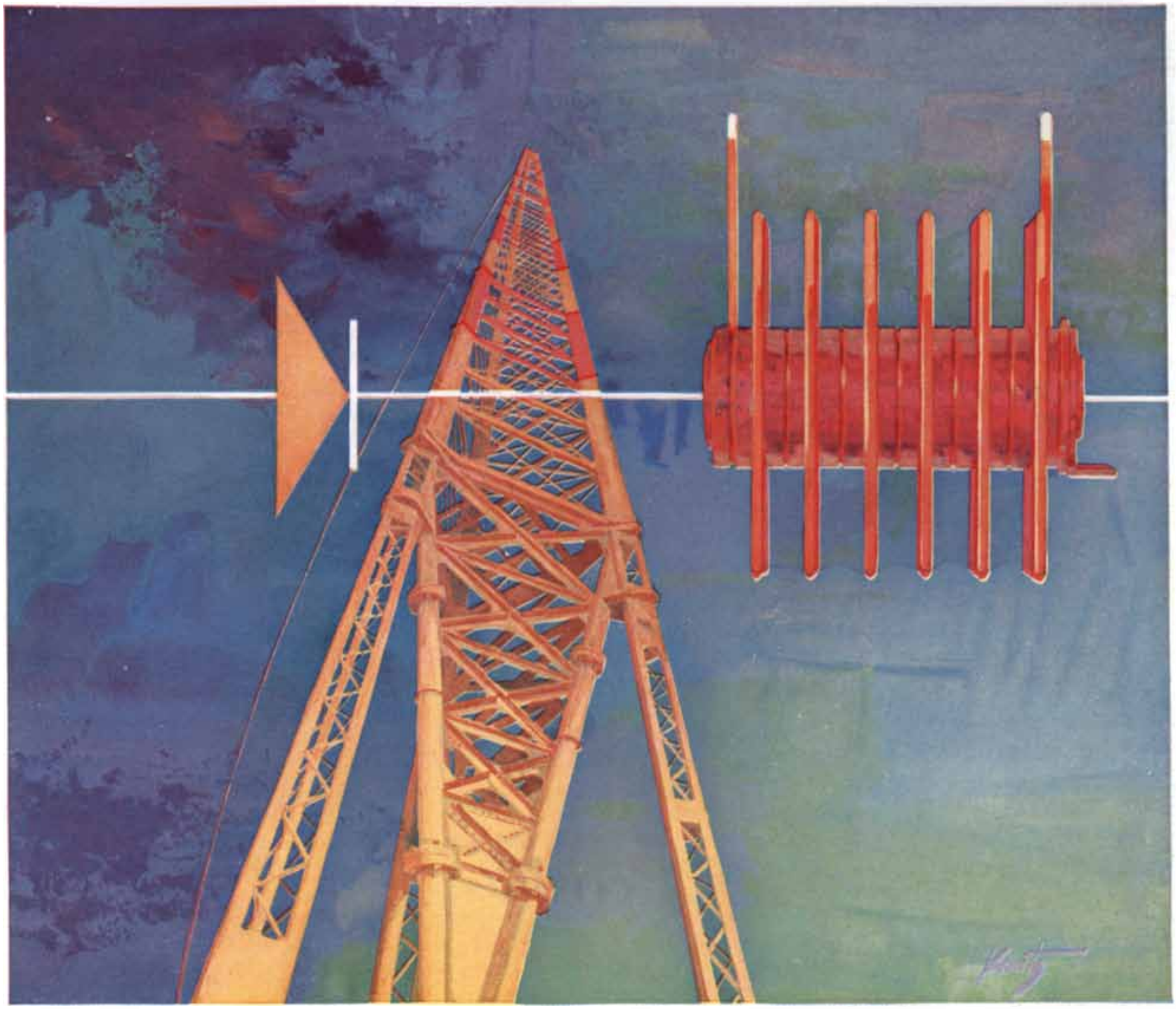
The fact that single interchange of any two blocks automatically reverses the parity underlies a particularly fiendish version of the puzzle marketed a few years ago in Canada. Here the squares are not numbered but lettered as shown in the illustration at right on this page. You show the squares to your victim in this arrangement, and then destroy it by sliding the blocks here and there at random. As you do so you slyly maneuver the second "R" into the upper left-hand corner before you hand over the puzzle. The victim naturally permits this "R" to stay in the corner while he tries to put the rest of the blocks in order—an impossible feat because as long as the "Rs" remain switched the desired arrangement has a different parity! The best the poor fellow can achieve is RATE YOUR MIND PLA.

Loyd's greatest puzzle is unquestionably the famous "Get off the Earth" paradox which he patented in 1896. A cardboard circle, riveted at the center to a square piece of cardboard, bears around its rim the pictures of 13 Chinese warriors. Part of each warrior is on the

1	2	3	4
5	6	7	8
9	10	11	12
13	15	14	

R	A	T	E
Y	O	U	R
M	I	N	D
P	A	L	

Loyd's "14-15" puzzle (left) *and a modern version of it* (right)



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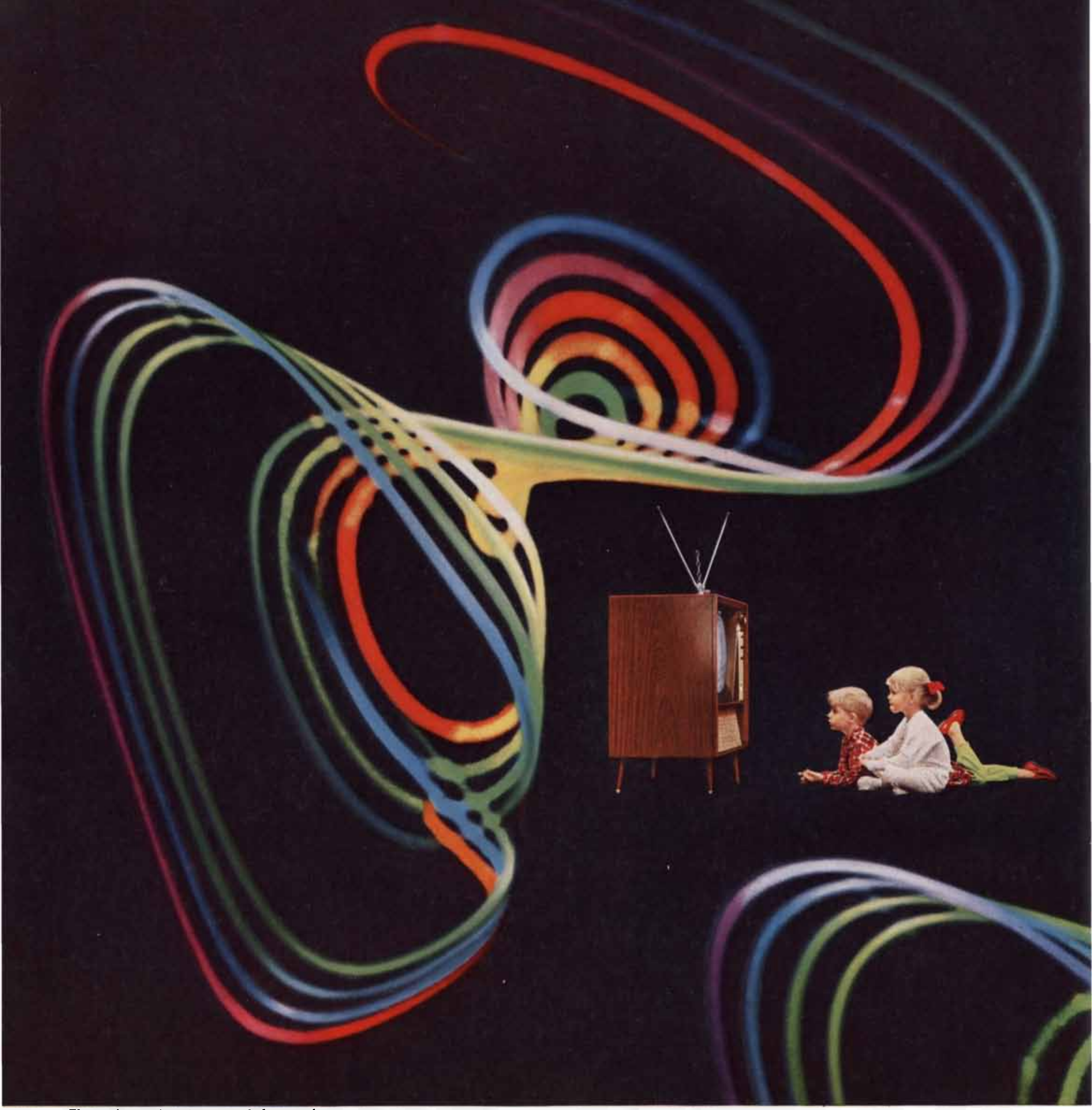


Electronic waveform is an actual photograph.

Loyd's "Get off the Earth" paradox. At left there are seven lions and seven hunters; at right, eight lions and six hunters

circle, and part on the square. When the wheel is turned slightly, the parts fit differently, and one warrior completely disappears! This puzzle has been reproduced so often that we show at the top of this page the less familiar, but in some ways more puzzling, version called "Teddy and the Lions." In one position of the wheel you see seven lions and seven hunters; in another, eight lions and six hunters. Where does the eighth lion come from? Which hunter vanishes and where does he go?

In 1914, three years after his father's death, Loyd junior issued a mammoth *Cyclopedia of Puzzles*, surely the greatest collection of problems ever assembled in one volume. The following brain teaser is taken from this fabulous, long-out-of-print work. It illustrates how cleverly the old master was able to take a simple problem, calling for nothing more than the ability to think clearly and to handle fractions, and dramatize it in such a way that it becomes an exciting challenge.

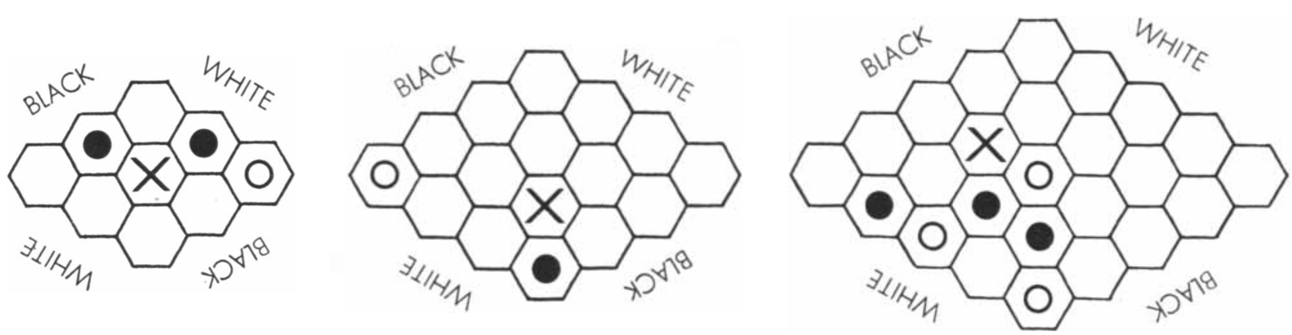
In Siam, Loyd explains, two kinds of fish are raised for their fighting qualities—a large white perch known as the kingfish and a small black carp called the devilfish. "Such antipathy exists between these two species that they attack each other on sight and battle to the death."

A kingfish can easily dispose of one or two of the little fish in just a few seconds. But the devilfish "are so agile and work together so harmoniously that three of the little fellows would just equal a big one, and they would battle for hours without results. So cleverly and scientifically do they carry on their line of attack that four of the little fellows would kill a large one in just three minutes and larger numbers would administer the *coup de grâce* proportionately quicker."

(That is, five devilfish would kill one kingfish in two minutes and 24 seconds, six in two minutes, and so on.)

If four kingfish are opposed to 13 devilfish, which side will win the fight and exactly how long will it take, assuming of course that the little fish cooperate in the most efficient manner? The answer to the problem will appear in this department next month.

Last month this department presented three problems of Hex, the game played on a board of hexagons. The solutions are given in the illustrations at the bottom of this page. Of course the complete sequence of plays cannot be shown. Only the one correct first move for "white" is indicated by the crosses.



The solutions to three problems of the game of Hex, posed here last month

THE AMATEUR SCIENTIST

An apparatus to study the metabolism of mice, and experiments with the eye

Nancy Rentschler, who goes to high school in Mayfield, Ohio, writes that she cannot claim any hobby because she enjoys so many. She plays the piano and the drums, knits, cooks, enjoys dry-fly fishing, does volunteer hospital work and roots fervently for the Cleveland Indians. She is also a consistent winner of blue ribbons at science fairs. Collecting this year's blue ribbon involved, among other things, learning how to pick up a mouse without getting nipped.

Miss Rentschler had to master this trick in order to study the metabolism of mice. Last January, while looking for a project to enter in her school science fair, she came across a textbook diagram of an apparatus to measure animal metabolism. This aroused her curiosity. She writes: "I didn't know very much about metabolism, but it seemed to me I could learn if the apparatus could be scaled down to the size required for a mouse. The apparatus would also make an exhibit worthy of the 220 entries in our science fair. I began to work on the apparatus late in January, and performed my first experiments with it about a month later.

"The mice I used were purchased through a pet shop. They had been inbred for three generations. At first I found it a bit difficult to handle them, but soon I learned to pick them up by the tail. After a week or so the mice became quite tame, although occasionally one would lose its temper during an experiment and try to bite the experimenter.

"For the purpose of my experiments I divided 15 mice into four groups, three in one group and four in each of the others. By placing each group on a diet or medication which differed from that of the others, I could study the effects of these differences on the metabolism of the animals. I followed the experimental method devised by the noted British physiologist J. S. Haldane in 1890. The apparatus consists mainly of an animal chamber and five flasks of chemicals interconnected by tubing so that a controlled stream of air can flow through the system [*drawing on opposite page*]. The purpose of the apparatus is to measure the amount of oxygen taken up by the animal, and the amount of carbon dioxide expelled. The ratio of oxygen inhaled to carbon dioxide exhaled by the animal during a given period indicates the rate of its metabolism, and is called the 'respiratory quotient.' This quotient varies with the diet of the animal. When the animal is fed a carbohydrate such as sugar, the ratio is 1. When it is fed fats, the ratio varies slightly with the composition of the fat but averages .7. The ratio for proteins also varies, but averages .8. The ratio of alcohol is .667. The respiratory quotients of normal animals under average conditions usually lie between .72 and .97.

"Each flask of the apparatus is fitted with a rubber stopper and two glass tubes about half an inch in diameter. One tube reaches to within an inch of the bottom of the flask and the other just passes through the stopper. Air entering the flasks through the longer tubes is exhausted through the shorter ones. The first and fourth flasks in the series (not counting the animal chamber) are filled to a depth of about three inches with soda lime, which absorbs carbon dioxide. The second and third flasks contain the same amount of calcium chloride. The fifth flask is charged with pumice stone and sulfuric acid. These last three flasks absorb water vapor. Ideally all three should contain pumice and sulfuric acid. I found the pumice difficult to prepare, so I made enough for one flask (to satisfy myself that I could prepare it) and 'made do' with calcium chloride in the other two. The pumice is used in lumps about half an inch in diameter. Mine came from cosmetic counters, which proved to be a costly source. I learned later that chemical supply dealers list pumice at 50 cents a pound. The stone is activated by heating it to redness with an acetylene torch and dropping it, while it is still hot, into concentrated sulfuric acid. The excess acid is then allowed to drain off. The soda lime is prepared by mixing lime with a solution of sodium hydroxide in the proportion of one ounce of sodium hydroxide (by weight) to two and a half ounces of water (by volume). Lime is added until the mixture becomes dry. The powder is then separated from the coarse particles by means of a fine sieve and discarded. Large lumps are broken down. It is the intermediate fragments—those which pass through a sieve of five meshes per inch—that are used for charging the flasks. The absorbing power of soda lime does not last long, and I had to make additional batches as the experiments progressed.

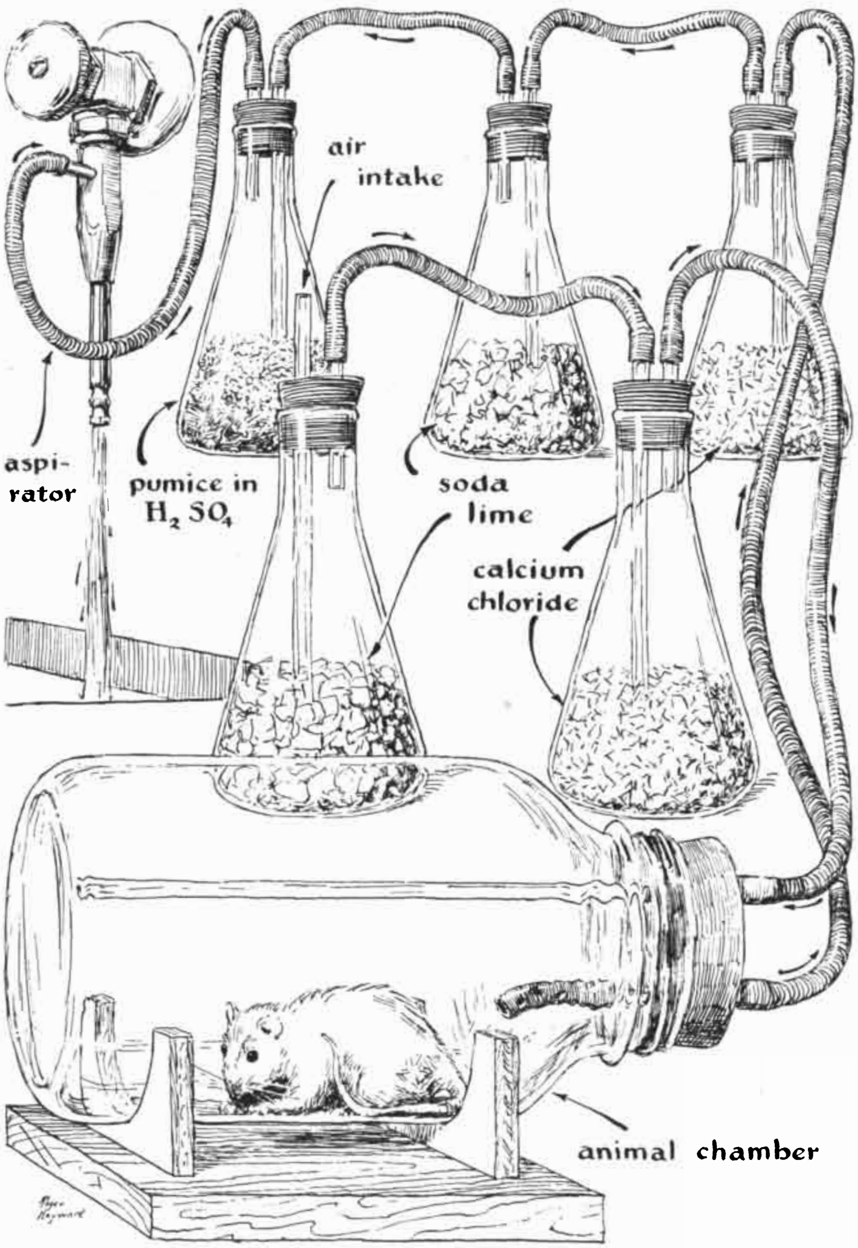
"My animal chamber was a two-quart canning jar. I found it necessary to shield the exhaust tube of the chamber to keep it from pinning the mice. Before I added the shield, this happened several times, spoiling the experiment and injuring the mouse. The shield is merely a short length of rubber tubing with a slit or a few holes cut in it. It is slipped over the shorter glass tube inside the chamber. No damage is done when a mouse brushes against the end of the tube because the slit provides a second exhaust port.

"The entire system must be airtight. Close-fitting stoppers should be used and all joints coated with either wax or plastic cement. The rubber tubing should be as short and straight as possible, and should be tightly fitted to the glass tubes. Air was pulled through the apparatus by means of an aspirator attached to a water faucet.

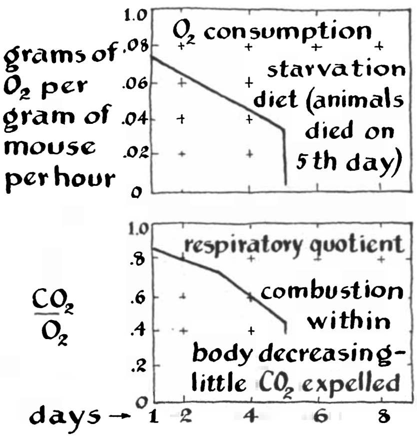
"Air normally contains about 3 per cent carbon dioxide and a varying amount of water vapor. Both are removed by the first and second flasks. Thus air free of water vapor and carbon dioxide flows into the animal chamber. The animal inhales oxygen and exhales carbon dioxide and water vapor. The latter are absorbed by the remaining flasks. The increase in weight of the third flask indicates the amount of water vapor given off by the animal. The fourth and fifth flasks measure the amount of carbon dioxide (which reacts with the soda lime in the fourth flask to form carbonic acid). The fourth and fifth flasks must be weighed together because the soda lime may give up moisture to the dry air and thus lose weight.

"In setting up the apparatus for a test run, the last three flasks are weighed, the fourth and fifth together. The animal is then placed in the chamber, which is stoppered and weighed. The test run is timed from this moment. The chamber is now connected to the apparatus and the air pump started. I ran the mice in each group for a total time of one hour. At the end of this period the pump is stopped and the chamber removed from the apparatus, stoppered and weighed again. The third, fourth and fifth flasks are also weighed.

"The respiratory quotient may now be calculated. The combined weight of the mouse and chamber at the beginning of the run minus their weight at the end of the run equals how much weight the mouse has lost. The weight of the third flask at the end of the run minus its weight at the beginning equals the amount of water absorbed by the cal-



An amateur's apparatus for measuring the metabolism of mice



Metabolic graphs of starved mice

cium chloride and lost by the mouse. The weight of the fourth and fifth flasks at the end of the run minus their weight at the beginning equals the amount of carbonic acid formed. The total weight of water and carbon dioxide absorbed minus the loss in weight of the mouse equals the weight of oxygen absorbed. The respiratory quotient is determined by multiplying the weight of the carbonic acid by the fraction 32/44 and dividing the result by the weight of oxygen absorbed. The quantity 32/44 is the ratio of the molecular weight of oxygen to that of carbon dioxide. Its use in the equation indicates the amount of carbon dioxide represented by the carbonic acid.

"I used two of my four groups of mice to study the effects of diet on metabolism. With the other two groups I investigated the metabolic effect of the activity of the thyroid gland. The first group of four mice was given only water. Although mice normally live about nine days without food, these died after four days. It is likely that they contracted pneumonia because their resistance was low. Their respiratory quotient dropped slightly from the beginning of the experiment but stayed within the normal limit of .7 to 1 for the first three days. It plunged sharply just before the animals died. Oxygen consumption, however, decreased at a constant rate throughout the period of observation. At the conclusion of the experiment I plotted graphs of both oxygen consumption and respiratory quotient [*illustration at top of this page*].

"In the second group of mice a 17 per cent solution of ethyl alcohol was substituted for water. Each mouse also received one gram of rabbit pellets per day beginning on February 26. On March 4 I found the mice shivering and huddled together in their cage. Fearing that they might die if a test were attempted, I fed them immediately and wrapped them in warm rags. Their ration was doubled for two days and then lowered to a gram and a half on the third day. One mouse died on March 9 and another the following day. I attempted to study the remaining two in the metabolism cage but their rate of respiration was so low that no results were detectable at the end of a two-hour run. According to a doctor friend whom I consulted during the experiments, the mice in this group died of semistarvation and extreme intoxication ending in pneumonia and shock. The oxygen consumption of the group increased sharply during the first three days of the test, dropped for two days and then climbed gradually to a peak just before the animals died. The respiratory quotient, although low, remained within normal limits almost to the end. A restricted diet with an excess of alcohol causes fat to accumulate in the liver and retard some of its functions. The results of this experiment were also plotted in graphs [*top illustration on opposite page*].

"On February 27 a group of four mice was started on a mixture of powdered rabbit pellets into which .1 per cent of desiccated thyroid gland had been mixed. Because this medication stimulates the thyroid the mice, which were permitted to eat as much as they would consume, gained weight steadily during the experiment. At one point the apparatus developed a defect and two mice suffocated. I continued with the remaining pair. Oxygen consumption appeared to drop during the final days of the experiment, but this too may have been due to a defect in the apparatus. The respiratory quotient remained below normal almost from the beginning and indicated no trend [*middle illustration on opposite page*].

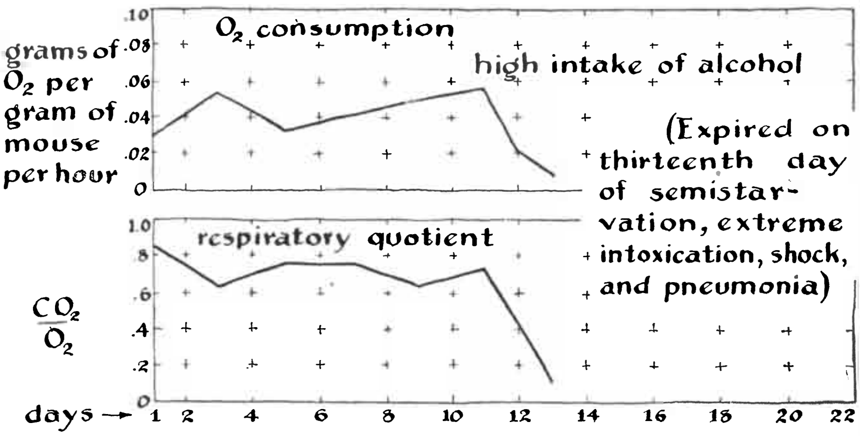
"The final group of three mice was injected with 100 microcuries of radioactive iodine (I-131) on February 26. This proved to be an overdose which destroyed the thyroid gland in about four weeks. The injections were administered in a medical laboratory, where the mice were kept for three days. Upon their return they were supplied with as much water and rabbit pellets as they would consume. The outward appearance of the group did not change during the period of the test. Oxygen consumption fell gradually during the first eight days and then increased to about double the minimum value on the 14th day. Thereafter it dropped more or less gradually to 10 per cent of its initial value on the 22nd day. The respiratory quotient also varied widely during the experiment but showed a gradual decrease until the final day of the run, when it shot up from a near zero value to normal [*bottom illustration on opposite page*]. These changes were expected because the thyroid was slowly deteriorating and its production dropped in proportion.

"These experiments have been the most rewarding, although the most difficult, of my science projects to date. Last year I worked with blood sugar, making my own tests. The year before I attempted a series of genetic experiments with mormoniella wasps. Although I cannot claim biology as a full-time hobby, it has interested me for as long as I can remember. Few hobbies, it seems to me, confront the amateur with such a variety of challenges."

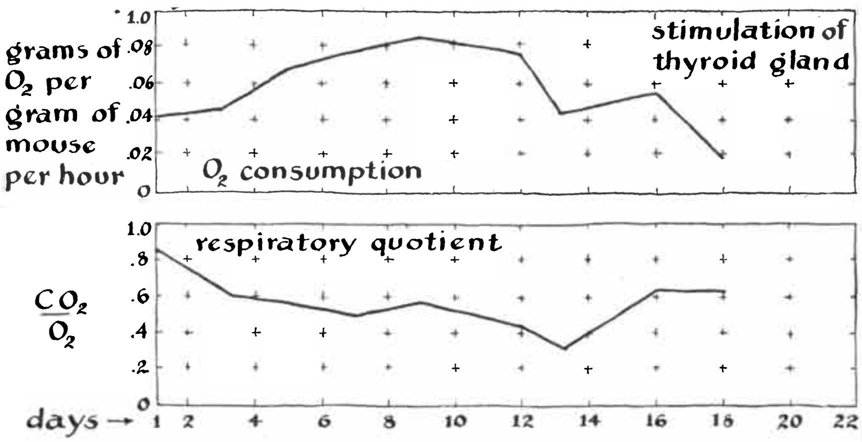
If you like to while away the time performing experiments that do not require apparatus, you will find much solace in the mysterious operation of human vision. You already own a pair of excellent optical instruments for such experimentation: your eyes. With these, plus pencil and paper, you are all set. If, in addition, you happen to have a pair of pocket mirrors, a couple of short-focus lenses and a stereoscope, you can really astonish yourself.

As a starter, draw a rectangle about three inches wide and two inches high and divide it by a horizontal line a quarter of the way down from the top. Then draw a series of disks diagonally across the bottom portion which gradually diminish in size, as shown in the illustration at the top of page 132. Common sense tells you that you have made a flat drawing. Yet your brain insists that it is a three-dimensional representation—especially if you judiciously shade the disks. You get the impression of a series of spheres which run from the foreground to a "vanishing point" on the horizon. It took the painters of the Renaissance a century to perfect this trick of representing three-dimensional reality in two dimensions. The "projective geometry" on which it is based is today an integral part of physics.

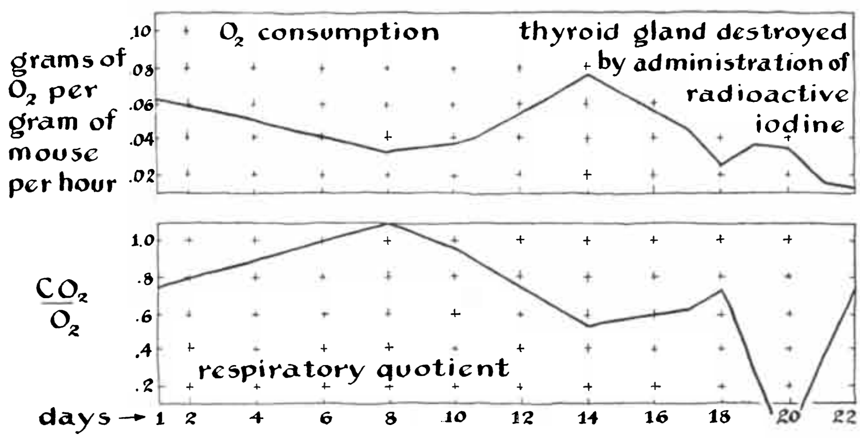
There is another method of representing three-dimensional reality in two dimensions which creates an even more dramatic visual impression. Make two rectangles, each an inch and a half wide by an inch and a quarter high. They should be spaced about two and a half inches apart from center to center. Now draw a horizontal line through the center of each, dividing the rectangles into two equal parts from top to bottom. Next make a shaded, quarter-inch disk precisely in the center of each horizontal line. Flank the disk in the drawing at left with an identical pair of disks spaced 3/16 of an inch from it. Make a similar pair on the horizontal line of the drawing at right, but space them 5/16 of an inch from the middle disk [*see bottom of next page*]. To the casual observer there is certainly nothing in this pair of drawings to suggest relief in three dimensions. But when you view the drawing in a stereoscope, which causes the pair of rectangles to blend into a single image, the disk at left is seen as a sphere floating in space above the plane of the paper. The center disk will appear as a sphere in the plane of the paper while the right one will seem to float in space



Graphs for mice fed on alcohol



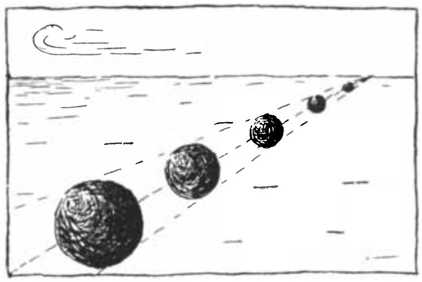
Graphs for mice whose thyroid glands had been stimulated



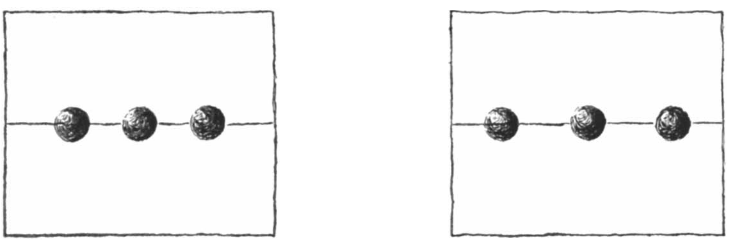
Graphs for mice whose thyroid glands had been destroyed behind the paper. With a little practice you can observe this effect without a stereoscope. Locate the drawing about two feet away and place the index fingers of both hands just outside your eyes. Now, while continuing to look at the drawing, move your hands slowly toward the drawing. Your left eye will see the tip of your left index finger and your right eye the tip of your right finger. As your hands advance, you will become conscious of *four* rectangles on the paper. Your brain is accepting the independent images presented by each eye. Now the inner pair of images will gradually overlap. Finally they will blend. When this is accomplished, transfer your full attention to the fused image. It will appear in three dimensions, just as though it were seen through the stereoscope. This is called "wide-eyed" stereoscopic seeing. You can also see the drawings in three dimensions without a stereoscope by the "cross-eyed" method. To achieve this you use only one finger. Place the drawing about two feet away, as before. Now put the tip of one index finger on the bridge of your nose and while looking toward the drawing slowly move your finger toward it, focusing your eyes on the tip. Again you will become conscious of four rectangles on the paper. Gradually, as your finger advances, the innermost pair will fuse as in the wide-eyed method and you will see the center drawing in three dimensions. It will differ from the wide-eyed view, however, in two major respects. The fused image will be smaller by about a third because, among other things, the optical path between the eyes and paper is now longer. You will also observe that the two outermost spheres will have exchanged position. The sphere at right now floats in front of the plane of the paper and the one at left behind it! The relief has been inverted.

Roger Hayward, who illustrates this department, has amused himself at odd moments for the past 30 years by learning to make stereoscopic drawings and investigating stereovision. "Three-dimensional drawings are not nearly as hard to do as one would imagine," he writes. "This is due to the tolerance of the eye, provided, of course, you understand what you think you see. If what you appear to see is inconsistent in geometry, that is, in perspective, or inconsistent in the effect of light and shade, the brain is apt to reject the stereoscopic effect. The picture will lack the apparent relief of 3-D and will appear relatively flat. This is illustrated by the pairs of drawings on page 134. The top pair, which is drawn for cross-eyed viewing, shows a prism lying in front of a screen. Both objects are in the foreground of a long room. The scene is lighted from the upper left; part of a window can be seen in the rear wall. The bottom stereo pair shows the same scene but is drawn to be viewed either by the wide-eyed method or through a conventional stereoscope. Let us assume that you either have access to a stereoscope or have mastered the art of wide-eyed viewing. On examining the drawing you will see the folded screen with a black band along the top and near the bottom. Part of the screen has been folded back and can be seen over the top of its front portion. The prism extends out in front and the screen casts a shadow on the right wall of the room. All this has the effect of a scene viewed in normal perspective with a self-consistent pattern of light and shade, although the pattern is a pretty conventional one.

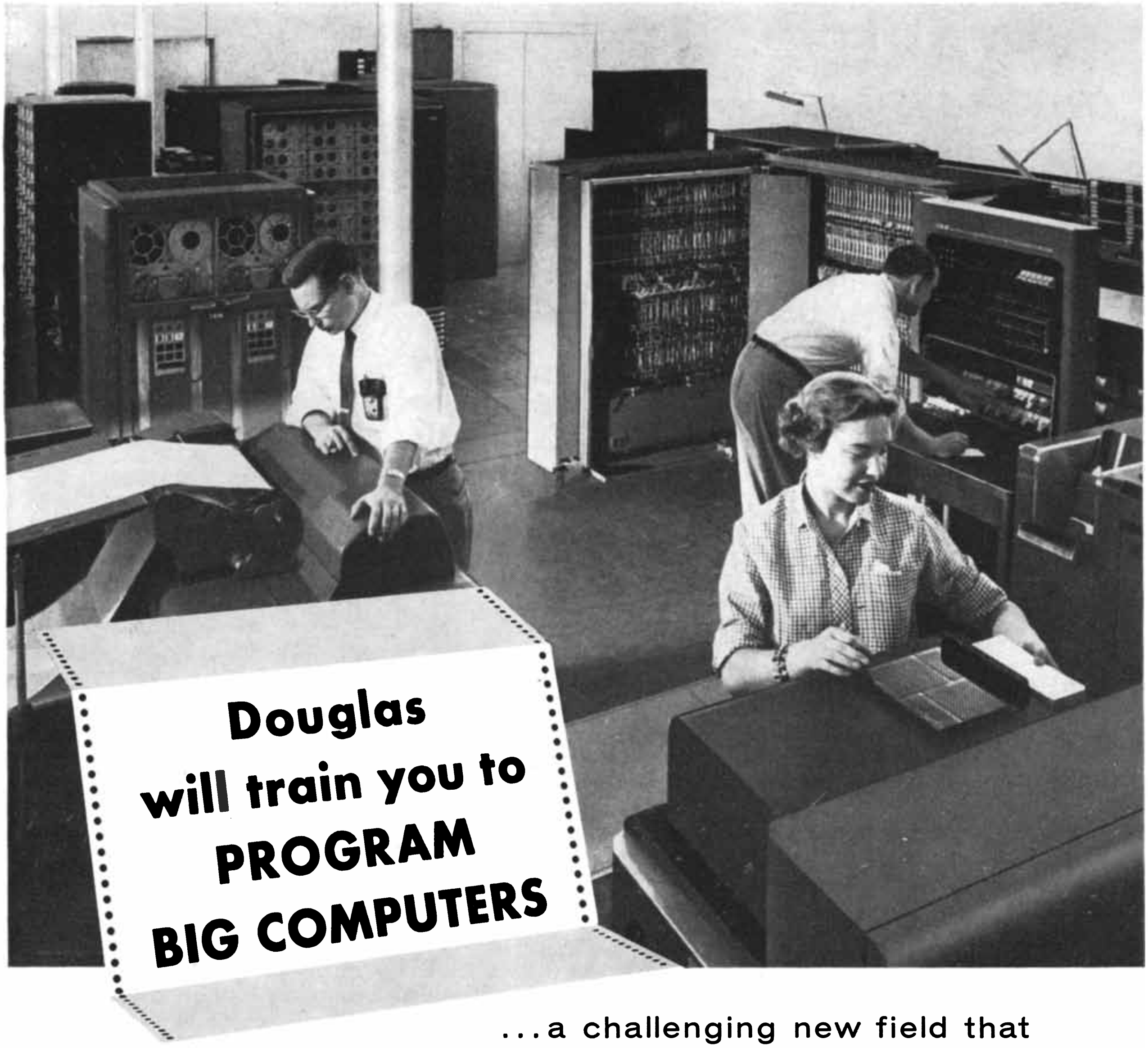
"Now change to either cross-eyed viewing or substitute the upper drawing for the lower one in the stereoscope. The relief will appear in reverse, near objects seeming smaller than far ones. The



Three dimensions by projective geometry



Three dimensions by stereoscopic drawings



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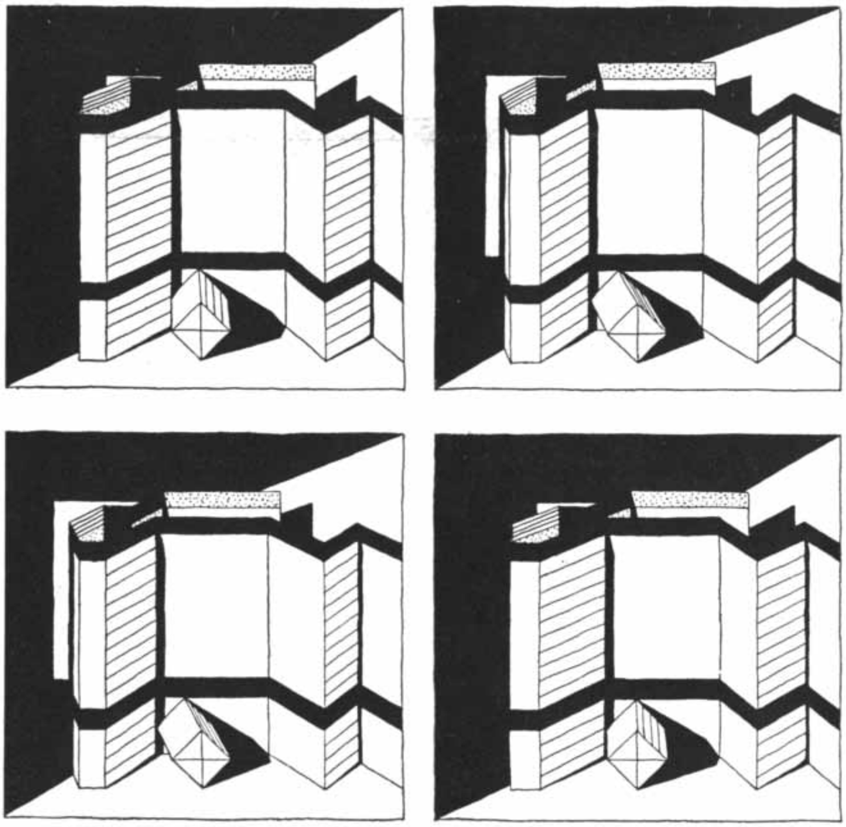


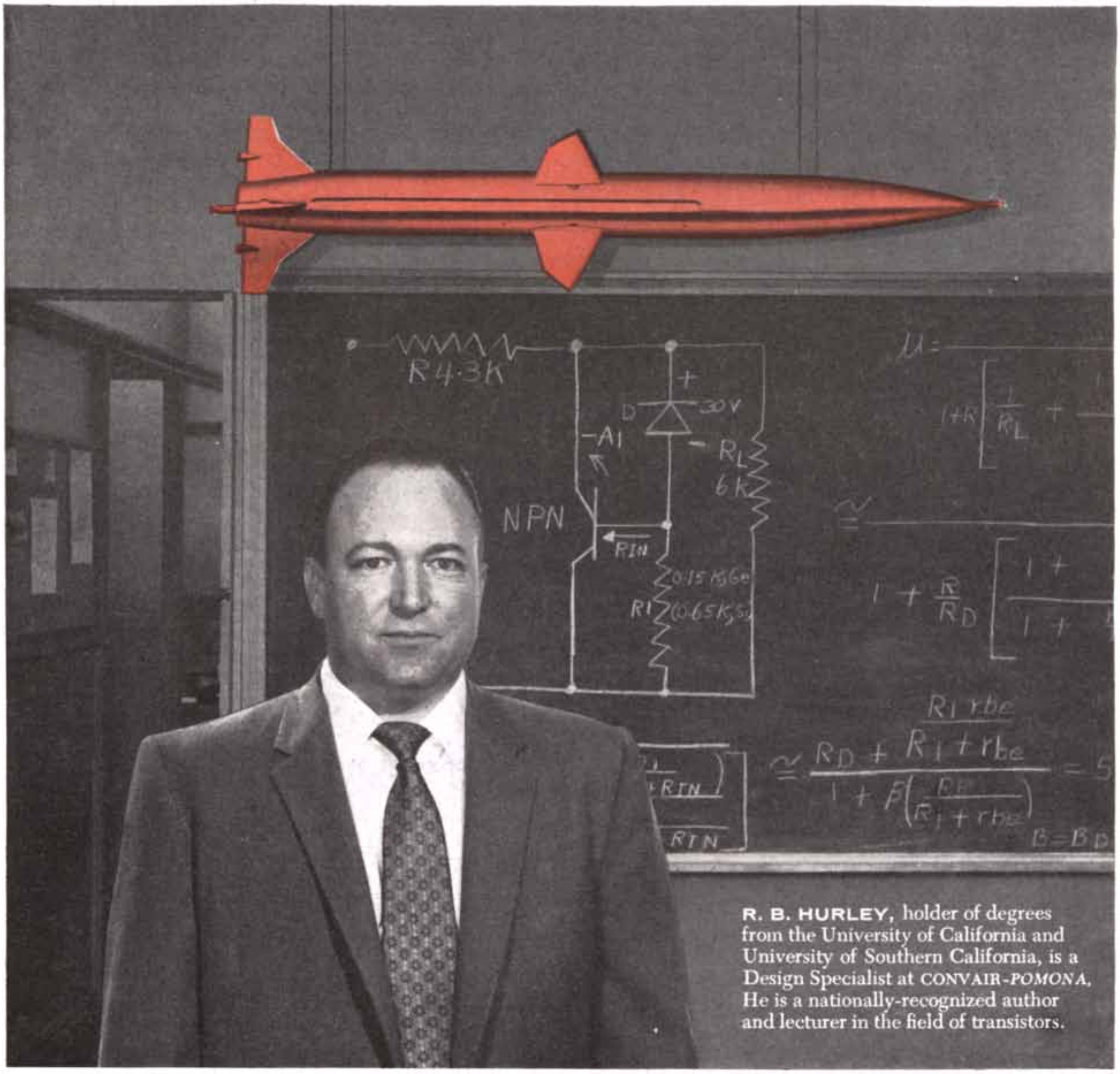
Stereoscopic drawings for "cross-eyed" viewing (top) *and "wide-eyed" viewing* (bottom)

folded portion of the screen will seem nearer than the front part, which does not make sense. Other parts of the scene seem to be linked in a fuzzy sort of jumble. From this experiment one can conclude that binocular vision is destroyed when violence is done to the principles of perspective. A near object which partly obscures a far one is nonsense which the mind simply refuses to accept. But if a figure is consistent in perspective and in light and shade, especially if the figure is unfamiliar, the mind will accept it as representing reality, however exotic the forms may appear.

"It is possible to investigate some of the limits within which the mind will accept misinformation from the eyes by means of an instrument called the pseudoscope, a binocular-like device which enjoyed brief popularity shortly after Sir Charles Wheatstone invented the stereoscope early in the 19th century. Diagrams of four versions of this instrument appear on page 136. Pseudoscopes alter the way in which the eyes normally present information to the brain. Some versions interchange the eye positions, in effect causing the left eye to see from the position of the right eye and the right eye from the position of the left. Others combine this interchange with image inversion, exaggerate the spacing between the eyes and so on.

"A pseudoscope can easily be made by holding up two hand mirrors, one somewhat to the left of the left eye and the other in front of the right eye. The angles at which the mirrors are held should be such that the image reflected from the mirror at left is directed into the right eye by the mirror at right. In effect, this causes the right eye to see from a position somewhat to the left of the left eye. The defect of this arrangement is that the optical path for the right eye is longer than that for the left; hence the image presented to the right eye is abnormally small. For objects at a distance of 10 feet or more the difference in image size is of little consequence, however, because of the curious fact that good binocular vision can be had even if one of the images is quite distorted. Accordingly an interesting inversion of relief will appear when the mirrors are adjusted so that the doubly reflected image fuses with the one seen normally by the left eye. The optical arrangement of a pseudoscope of this type is shown at the top of the illustration on page 136.

"Other versions of the pseudoscope can be made with prisms, with two sets



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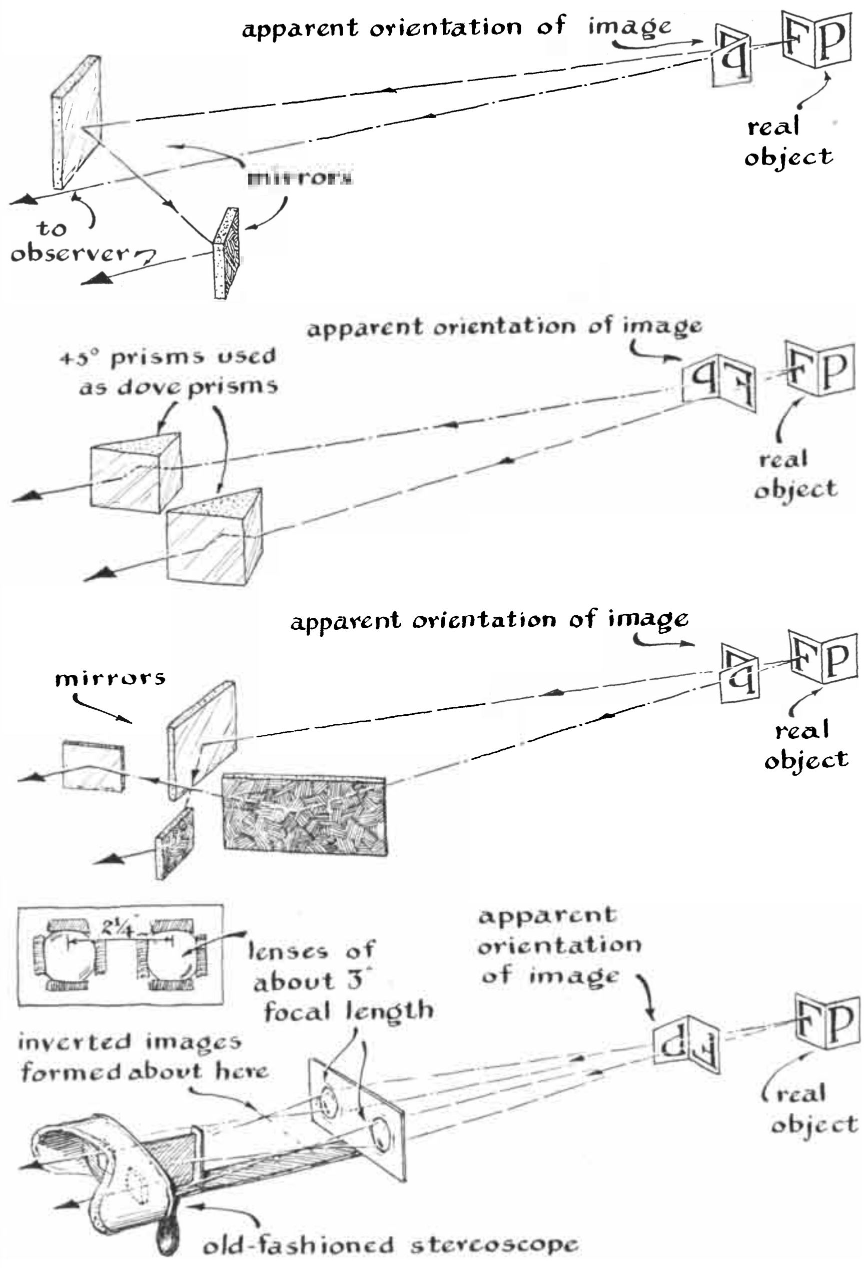
of mirror pairs or by mounting a pair of short-focus lenses in the cardholder of a conventional stereoscope. Optical arrangements for these are shown as the second, third and fourth drawings in the illustration on this page. Holders for the optical parts need not be elaborate. I merely laid the prisms of the second arrangement between two pieces of wood, for example, and held the whole thing together with rubber bands. The mirrors of the third device may be stuck to a small board with sealing wax and adjusted for image fusion while the wax is still soft.

"Martin Gardner, who edits the *Scientific American* department 'Mathematical Games,' first called my attention to the stereoscope-pseudoscope represented in the fourth drawing, and suggested an interesting experiment for it—viewing the effect of a small ball rolling inside a round-bottomed bowl. With no shadows to indicate perspective, the mind accepts the inversion perfectly. Released at the edge of the bowl, the ball promptly climbs up one side of what appears to be a mound, rolls down the other side and promptly returns. Finally, after a number of diminishing oscillations, the ball comes to rest on the summit of the mound!"



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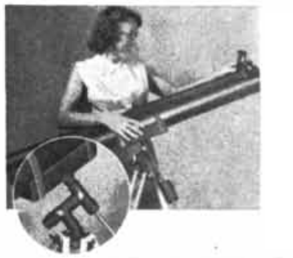

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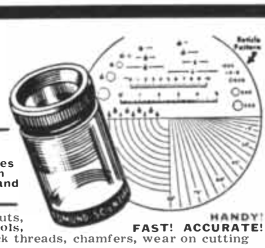

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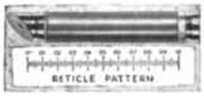

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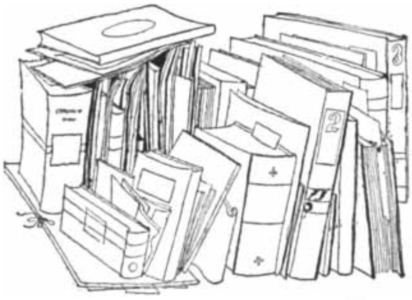


BOOKS

An introduction to biology as a solution of difficulties in the teaching of science

by Jane Oppenheimer

LIFE: AN INTRODUCTION TO BIOLOGY, by George Gaylord Simpson, Colin S. Pittendrigh and Lewis H. Tiffany. Harcourt, Brace and Company ($10).

This book is published in two editions, one for the general reader and the other for the beginning college student of biology. It is clearly designed, however, for the latter audience. As a textbook of biology it is completely unique, both from the standpoint of the student and that of the teacher. It represents a fresh approach to the problem of introducing the student to a field that is much farther removed from his experience than it once was, and thus it demands to be taken very seriously indeed. This review will discuss it as a textbook, and will then relate some of its superiorities and shortcomings to some critical problems in the elementary teaching of science.

Life: An Introduction to Biology is consciously addressed to the new generation of students. It says: "If you would like to return to nature, you were born too late." Today nature (insofar as nature can be separated from man) is crashing before the bulldozers, a tragedy whose magnitude can be guessed only by those who, like Albert Schweitzer, elevate reverence for life to the rank of the highest human value. It is a tragedy on such a grand scale that the fact that it alters the teaching and learning of elementary biology is only one of its minor aspects. But it is this aspect which makes biology an especially difficult problem for the teacher and the student. In chemistry and in physics, after all, the molecule and the atom remain unchanged.

The range of information and interpretation encompassed by the authors far surpasses anything approached by recent texts. After a brief introduction the book takes up the cell as the unit of life, discussing this at the outset with reference to the organism as a whole and only subsequently in terms of its chemical constituents and mechanisms. The following section is devoted to the maintenance and integration of the organism; the next to reproduction. Then there ensue discussions of the elementary processes of evolution (at a far less elementary level than usual) and of the diversity of life. The life of populations and communities is next taken up, both in general and with special reference to human species and groups. The next to the last section deals with the history of life, and the final one with the history of biology. Although this brief outline may not indicate it, there is scarcely a field of modern biology which is not at least lightly touched.

The book is as accurate as any book which covers such a tremendous variety of topics can be. As it moves from field to field its quality is inevitably uneven, but it is brilliant in the clarity of its exposition of the chemistry and energetics of the cell, and of the chemistry of genetics. It is weak in its presentation of facts and concepts in ontogeny: the development of the individual organism. The final section on history might have been omitted without great loss.

It is strange that authors so conscious of history in the context of evolution lack perspective in regard to the history of the individual and the history of biology. Not only does the final chapter on history leave something to be desired, but also a number of the rather scanty historical references in the text tend to be unjustifiably sardonic about early ideas. "The ancient Greeks were wonderful people and are rightly honored in all histories of science, and yet sometimes a horrid suspicion arises that we would understand life better today if some of their philosophical notions had been forgotten." A horrid suspicion arises in the mind of this reviewer that there are aspects of the continuity and development of ideas which the authors have still to appreciate.

The book employs many pedagogic tricks which will interest not only teachers of biology but also those of other sciences. It claims to follow a "principles approach," of which more will be said below. It avoids the use of too much technical language: it does so by omitting from the text much of the vocabulary and content of many elementary textbooks. The authors take varied measures to compensate for what they have deliberately omitted from the text. The volume is richly illustrated with photographs (those by Douglas P. Wilson are especially beautiful) and many excellent drawings and diagrams. The illustrations are accompanied by extensive captions which supply information omitted from the text; these the reader is free to take or leave. There is further amplification of the text in an abundance of footnotes. Each chapter of the book is simply and concisely outlined at the end; this fortunately leaves no room for the questions which often clutter up the rear of textbook chapters. Instead the text is liberally interspersed with queries addressed to the reader. Sometimes the questions are answerable, serving the function of letting the student know how it feels to be a scientist; sometimes they are unanswerable, which fulfills the same purpose.

The book often follows one of the canons of modern advertising in relating topics to the reader's personal interests by addressing him as "you." The authors include discussions of fields which presently border on biology; for example, behavior and learning are discussed from the point of view of the psychologist as well as that of the biologist. Their lingo is up to date, too: they speak of "conceptual schemes," "models" and "information." In their preface the authors specifically disclaim any pretense of following what they call the fad of centering the treatment on man, but in many cases they do so, perhaps unconsciously, to a greater degree than they intend. In the case of these authors, this reflects an attitude of mind and is no mere pedagogic ruse.

The basic attitudes of the authors,

after all, are the really significant attributes of the book. One such attitude may well be important not only to the biologists of tomorrow who use this text as beginners, but also to all intellectuals of the day after tomorrow. While a brief introduction to the Darwinian concept of evolution is included in one of the early introductory chapters, the text's own exposition of the evolutionary concept is couched not in the terms and concepts which Darwin used, but in those of modern population genetics. Thus students educated by this book will be the first large population to hold a 20th-century rather than a 19th-century view of evolution. Inasmuch as the new concept of evolution, like the old, may influence thought far beyond the confines of biology, the book for this reason alone is deeply significant.

But if the authors choose this grand and impersonal and cosmic view of nature as it is and was and may be, how do they fit man the microcosm into the macrocosm? It seems to this reviewer that man is set apart throughout the volume. In the section on the maintenance and integration of the organism he is often the example, and he is clearly considered the climax of vertebrate evolution. The emphasis on his superiorities sometimes excludes mention of the superiorities of other forms. For instance, the main discussion of the circulatory system attributes a four-chambered heart to mammals, and only 444 pages later is it barely mentioned that this is also characteristic of birds. If the authors tend to underestimate the birds, it is because of their frank admiration of the human brain, which they consider "the greatest marvel in the universe." It cannot be denied that man has considerable intelligence, but the brains of birds and bees, though they function differently from the brain of man, are intricate and successful mechanisms in their own ways. From the point of view of cosmic evolution there may be some question as to what is high: the birds have not invented a cobalt bomb.

Yet it is not the emphasis on human superiority, which many may believe justified, that is unbecoming to a textbook of biology so much as an accompanying tendency to denigrate other organisms. "Have you ever meditated on the fact that characteristics we admire, such as brain development, keen senses, and skillful coordination, are more likely than not to be best developed in predaceous animals, while animals that lead quiet, respectable lives seem to have little else to recommend them?" They have all that is needed to recommend them to members of their own species. Again, in writing of experiments on behavior in the earthworm, the authors say: "No one, not even its trainer, really cares much about the earthworm as an individual or even as a representative of its species." Some people do care!

A further consequence of the emphasis on human superiority is a tacit pragmatism which imbues sections of the text. This is due partly to the deliberate attempt to cover not only the biological but also the social features of man's relationship to nature: conservation, after all, is an intensely practical issue. But it may also be due to the style of the book. This is more journalistic than literary, and sometimes the choice of words is not too particular. For example, it quotes Samuel Butler to the effect that the "hen is the egg's device for laying another egg." Now what Samuel Butler actually said, at least in his *Life and Habit,* was something different, namely, that "a hen is only an egg's way of making another egg." He was worrying about hens not as gadgets, but as individuals. The lapse is an interesting one, an intimation that in the authors' minds problems of individuality belong to the 19th century of the old-fashioned nature rather than to the 20th century of population genetics. Yet the paradox remains that the fascination of biology to the novice as well as to the specialist depends even now on the relationship of the individual to his group, and not on considerations of the group alone.

A striking feature of the book is its physical size. Its weight, crudely measured on a bathroom scale, is three pounds, about as much as that of a late teen-age student's brain. Is this a fair balance? How much of the contents can a mind completely untrained in biology and unversed in knowledge of nature be expected to encompass? This is an embarrassing question, not only for the authors of the book but for all teachers of elementary science. How much science can be taught in a year, and by what method? There is too much for one mind to learn in a lifetime. Did Simpson, or Pittendrigh, or Tiffany know every fact and theory incorporated in this text before setting out to write it? Can their beginning students be expected to learn in an academic year what they jointly took "long years" (I quote directly from the preface) to assemble?

One escape from submergence in sheer quantity of information is that popular practice, followed by these authors and many others, called the "principles approach," a descriptive phrase that is anathema to those sufficiently old and old-fashioned to have been taught to avoid adjectival nouns. There may be some virtue in the phrase, because in biology the principles are only approximated, not attained. Biology does not yet rest on the kind of established principles that prevail in the physical sciences; it still operates at a different level of certainty, even at its most statistical. The present authors are not always too clear in expressing what they consider their principles to be. "Materials have to pass through the cell membranes and therefore are subject to the principles of semipermeability and osmosis." Semipermeability may be a characteristic of a membrane; osmosis is a process. Both are phenomena, but are either of them principles? Again, the "principle of coupling endergonic reactions is the heart of the cell's mechanism for meeting its energy payments." Is the coupling of intracellular reactions a principle or is it a mechanism? If these are not the principles of biology, what are the principles and who has formulated them with precision?

The scientist believes he achieves his highest aim when he points out relationships. Modern students, poorly grounded (as indeed are many of their teachers by now) in classical languages, are loath to learn new vocabularies, and sometimes to learn new facts. It is a pity that modern information theory cannot convince them that it is the input of information that determines the output of the thinking device. The student clamors to learn ideas, not facts. How in science, which deals with phenomena, may an idea be comprehended in the absence of some knowledge of the phenomena? No idea of evolution is adequate without a recognition of the facts of historical change in organisms, whether these facts be couched in the 19th-century terms of Darwin or in the 20th-century ones of Simpson, Pittendrigh and Tiffany. To what degree detail can be omitted in favor of generalization is a problem that faces all teachers of elementary science.

If many scientific textbooks place a strong emphasis on principles, many of these same texts try to show the student how it feels to be a scientist, thus relegating themselves to the category of how-to-do-it books. Perhaps a textbook on logic can tell a student how it feels to be a logician, but can any verbal instruction in science, in the absence of work in the laboratory or the field or the computing room, intimate how it feels to be a scientist? Does attending a concert disclose how it felt to be Mozart? One of the most intelligent people I have

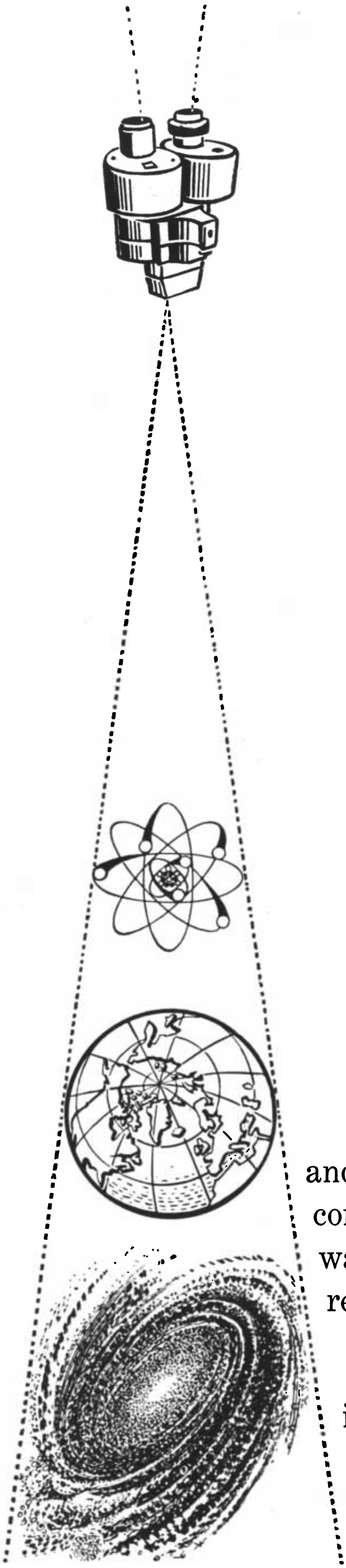
ever known, now a distinguished classicist, once told me that the only way she had learned what science was like was by not being able successfully to carry out experiments in the elementary physics laboratory. For those who are still old-fashioned enough to believe that laboratory instruction is an essential part of elementary scientific teaching, the omission of factual detail from assigned textbooks may lead to difficulties, unless exceptionally well-informed laboratory assistants are available.

Although the teacher of science has always had these problems, they have become more acute because there is so much more to teach and to learn today than there was a generation ago. When students were expected to memorize facts, and there were not too many facts to learn, there was less need to worry about getting science across. Now teaching science and writing textbooks become problems in public relations. There is some good in this situation; scientists have not always been articulate and have much to learn about expressing themselves clearly. There are also perils inherent in it, if in order to get their lessons across authors and teachers overemphasize what is useful to mankind rather than what is interesting for its own sake.

The problem becomes particularly acute at a moment when the scientist is suddenly becoming self-conscious with respect to his social responsibilities. Who is to speak with more authority on problems of conservation and erosion than the field biologist or his spokesman? Students wish to learn ideas and theories, and their professors wish to teach them some detailed facts, and administrative biologists wish them to become acquainted with social problems related to their science. But who can lay the groundwork for a beginning student to learn all these things in an academic year, as a fourth or a fifth of his full academic load? Perhaps the only solution is to present the student with just such a book as this one, which contains a little of everything, and let him absorb what he may. But by including all things within a single cover, the book does not solve the problem; it defers it to the learner. Dipping the slim rod of the mind into any single book can only be the beginning, not the end, of learning.

Short Reviews

ARCTIC FRONTIERS, by John Edwards Caswell. University of Oklahoma Press ($3.75). OPERATION DEEPFREEZE, by Rear Admiral George J. Dufek. Harcourt, Brace and Company ($5). THIN EDGE OF THE WORLD, by André Migot. Little, Brown and Company ($4.50). SPRING ON AN ARCTIC ISLAND, by Katharine Scherman. Little, Brown and Company ($5). QUEST FOR A CONTINENT, by Walter Sullivan. McGraw-Hill Book Company, Inc. ($5.50). Polar exploration is not what it used to be. It may be the blizzard of '88 will repeat so that New Yorkers can have a taste of the past, but the men who mush around the Arctic and Antarctic today cannot hope to relive the adventures of an Amundsen, a Peary, a Nansen, a Scott or a Shackleton. The weather in these regions is as bitter as ever; the land as desolate and the ice as relentless. Dogs still play a big part in transportation. The nights are long. The expedition members face many dangers, are oppressed by monotony, get lost and sometimes die. But in an age of radio telephones and aircraft, of self-propelled "weasels" and electric heating, of massive combined naval and air operations supported with almost unlimited funds and manpower, the lonely epic exertions of earlier days are not likely to recur. This group of books illustrates the changes which have taken place in man's assaults upon the polar frontiers. Caswell's fine history recounts the role of U. S. explorers in Arctic discovery from the De Haven expedition and the penetrations of Elisha Kent Kane in the 1850's to Robert Peary's famous race to the Pole in 1909. One of the merits of this book is its description of the scientific contributions of various expeditions, including some of the lesser known voyages whose achievements, though scientifically more important than Peary's, are obscured by his feat. The Dufek story provides the contrast to earlier undertakings. Dufek commanded the U. S. Navy Support Force Antarctica which executed Operation Deepfreeze, the most extensive (and expensive) polar expedition of all time. Large scientific bases were set up, unknown territories were explored, planes were landed at the South Pole, the admiral planted a flag. There were hazardous episodes, but everything came off pretty well; the main task of preparing for the International Geophysical Year was carried through. *Quest for a Continent* is by a New York *Times* correspondent who went on three U. S. expeditions to Antarctica. He presents a readable survey of exploration at the bottom of the world, beginning with Bouvet de Lozier, who first guessed that the drifting Antarctic ice fields, which he skirted for 1,000 miles without seeing any land (except for a small island which now bears his name), "could be produced only by a great land mass south of the ice which barred his way." Captain James Cook, Yves Joseph de Kerguelen-Tremarec and the 21-year-old mariner Nathaniel Palmer, who in 1821 in his tiny sloop *Hero* had an almost incredible encounter with the warships of Admiral Thaddeus von Bellingshausen of the Imperial Russian fleet near what is now known as the Palmer Archipelago, were among the earlier Antarctic pioneers. James Clark Ross, who set out to reach the South Magnetic Pole, Dumont d'Urville, who found the region which he named Adélie Land for his wife, Roald Amundsen, Frederick A. Cook, Ernest Shackleton, Robert Falcon Scott, Richard Evelyn Byrd were others whose intrepid labors opened the way for Operations Highjump and Windmill and the contemporary expeditions of many nations to the southern continent. *Thin Edge of the World* is a personal chronicle. Dr. Migot is a self-contemplative, strange, lonely man with a passion for strange, lonely places, preferably cold. His love of solitude and of danger was requited in a visit to desolate, storm-swept Kerguelen Island in the subarctic reaches of the Indian Ocean. In this forlorn French possession, with its "peculiar and vile climate" he spent a year as physician to the resident mission engaged in meteorological, geological and biological research. Where others considered their stay on the island a wretched and almost unendurable experience, not much better than penal servitude, Migot was happy. He got on no one's nerves because he kept silent; he gave no companionship and asked for none. He explored the island, fraternized with the penguins, studied the birds and observed the sea elephants with a characteristic mixture of loathing and affection. He was probably the first man ever to regret leaving Kerguelen, but his melancholy was soon forgotten in a further adventure with an Australian mission which set up a weather station on the Antarctic continent. We shall hear more from Dr. Migot and it will be worth reading, for he is as admirable and as sensitive a reporter as he is deep and out of joint. A more cheerful odyssey is Katharine Scherman's. For six weeks she lived with a group of eight American scientists on Bylot Island, an uninhabited and largely unexplored region 450 miles north of the Arctic Circle in the eastern Canadian Arctic. The time was spring and Miss Scherman was a witness to the brief vernal rebirth of this great stretch of treeless tundra. There were butterflies, bees and bright



flowers; large and small birds, which the author both watched and learned to eat; seals, narwhals and lemmings. She got to know the white men—two Hudson Bay Company traders, two constables of the Royal Canadian Mounted Police and three missionaries, one Anglican and two Catholic—of the nearest settlement, Pond Inlet, north of Baffin Island; she made friends with several of the Eskimos, whose life is part Ice Age and part 20th century (with outboard motors and high-powered rifles equipped with telescopes), a mixture which does not hold much promise for the future of these remarkable people. Miss Scherman is a woman of taste and courage, but her book is preachy and, for what it has to say, too long.

SCIENCE IN THE FEDERAL GOVERNMENT, by A. Hunter Dupree. Harvard University Press ($7.50). This history of the development of the policies and activities of the U. S. Government in science covers the period from 1787, when the Constitutional Convention nibbled at, quarreled over and finally rejected a plan to establish a national university, to 1940, when the threat of our involvement in World War II forced the realization that new weapons, as yet completely undeveloped, would very likely determine our survival and that what was needed was not merely greatly to expand Army and Navy research facilities but to bring all the nation's scientific resources to bear on research applicable to the war. At the Constitutional Convention one of the issues in debate was the extent of the central government's powers. Those who opposed Federal support for science and learning raised the specter of the political leviathan swallowing up the rights of states. The specter was not laid for a century and a half, and many attempts to enlarge Federal responsibility in science were blocked by this argument, or had to be disguised before receiving Congressional approval. Among the highlights of Dupree's account are the chapters on the use made of James Smithson's bequest to found an institution "for the increase and diffusion of knowledge among men"; the exciting 20-year period (1842-1861) of the great explorations and surveys; the role of the indefatigable Dallas Alexander Bache in promoting a corps of professional scientists in government; the evolution of research in agriculture; the activities of the Geological Survey; the short-lived (1884-1886) Allison Commission and its pet, the unborn Department of Science; the history of conservation, medical and public-health policies; the origins and adventures of the Bureau of Standards, the Forest Service and other Federal science agencies; the drastic curtailment of support for science during the Depression, and the efforts of President Roosevelt and Secretary Wallace to enlist the natural sciences in the social experiments of the New Deal. It cannot be said that the mass of administrative and organizational detail which the author has combed to produce this study invariably yields a thrilling harvest; many pages are crowded with minutiae which might safely have been left undisturbed in official reports. Moreover, this emphasis has forced the exclusion of material that would have furnished a broader and more revealing picture of science in government in relation to the general scientific, intellectual, political and economic scene in America. But Dupree has handled many situations and personalities with skill and animation, and there can be no doubt that as a result of his labors we have a better understanding of the emergence of the present (but not in all respects healthy) relationship that exists between science and the Federal Government.

ESSAYS IN METABOLISM, edited by Louis G. Welt. Little, Brown and Company ($6.50). The essays in this volume, apart from their scientific value, deserve recognition because they are offered as a tribute to the late John Punnett Peters, for many years professor of medicine at Yale. Dr. Peters was a gifted physician and a leader in research in clinical biochemistry. He also had a deep interest, to which he devoted much energy, in the improvement and widening of medical care. A courageous man, elevated in his social outlook, he often spoke out on behalf of unpopular causes. Thus it came about that, while serving as a consultant to the National Institutes of Health, his fitness to hold this office was challenged on grounds of loyalty. After a long-drawn-out procedure culminating in a perfunctory hearing, during which he was not confronted by his accusers, he was dismissed. Peters was a sensitive man, and in precarious health, but he determined on principle to fight the matter through, and ultimately the Supreme Court reversed the administrative determination. Shortly thereafter he died of a heart attack.

A CONTRIBUTION TO THE HERITAGE OF EVERY AMERICAN: THE CONSERVATION ACTIVITIES OF JOHN D. ROCKEFELLER, JR., by Nancy Newhall. Alfred A.

Knopf ($13.50). Any fool can make money, but it takes skill and imagination to spend it wisely. There are foundations which have not yet discovered this fact. John D. Rockefeller, Jr., inherited a vast fortune, which has multiplied. He has also spent a fortune, as did his father, on philanthropies, in support of education and scientific research, in conservation and the restoration of historical landmarks. He has taken thought to these activities and planned them with care and expert advice. The record of one aspect of his intelligent giving is presented in this colorful book. It describes the public gifts he has made of parks and roads; his efforts to preserve the magnificent Palisades on the Hudson, which quarrymen were gradually blasting away to make crushed stone for concrete; his benefactions which have enhanced the historical attractions of the Hudson River Valley; his contributions to Acadia, Shenandoah, Great Smoky Mountains, Yellowstone, Jackson Hole Basin and other national parks; his actions to preserve the California redwoods; and his well-known restoration of Williamsburg, Va. The text of this attractive volume and the many photographs, some in color, tell an impressive story of services from which the people of the U. S. will benefit for a long time to come.

THEORY OF LAND LOCOMOTION, by M. G. Bekker. The University of Michigan Press ($12.50). Motor vehicles are like domesticated animals. They are born, they are fed, watered and cared for, they are harnessed, they work and are imposed upon, they suffer from real and imaginary ailments, they respond best to their master's touch, they are balky and temperamental, they age, become enfeebled and die. They do not breed, but, on the other hand, with our help, they adapt themselves. The wheel is of course an ancient instrument of locomotion, and still the most widely used. But it requires some kind of a road or track. To cross a steppe, tundra, marsh, desert or mountain; to traverse snow, ice, soft or slippery ground; to move cross-country: each of these obstacles presents difficulties which the wheel-shod motor vehicle can scarcely overcome. Various auxiliaries to, and substitutes for, the wheel have therefore been invented, among them crawlers, caterpillars and skis. Colonel Bekker has devoted years to research in land locomotion, a subject of special concern to the military. In this study he presents a general theory of the subject, the foundation of a new type of applied mechanics. The topics discussed include locomotion on wheels, "morphology of motor vehicles and environment," soil and snow mechanics, track-laying vehicles, "trafficability of soils" and scale-model testing.

THE ANCIENT MAYA, by Sylvanus Griswold Morley, revised by George W. Brainerd. Stanford University Press ($10). This fine study of the Mayan civilization of Guatemala and Yucatán now appears in a third revised edition. It describes the region where the Maya lived, their history, manners and customs, and it compares their culture with that of other aboriginal American societies. Sylvanus Morley died in 1948; Dr. Brainerd of the University of California undertook a revision of the work to take into account recent discoveries, among them the wall paintings at Bonampak and the Palenque tomb. Unfortunately Brainerd died before completing his task, but a final chapter was added by his assistant, Betty Bell, who was well acquainted with his intentions. Together the text and illustrations form one of the most readable classics of archaeological literature.

ANIMAL NAVIGATION, by J. D. Carthy. Charles Scribner's Sons ($3.95). How animals find their way about is the subject of this charming book. The sense of smell guides, among others, planarians and army ants. Wasps have an extraordinary ability to map the terrain where they hunt and make their nests. Bees steer themselves by their perception of polarized light. Birds have a wonderful memory for contours and landmarks, but how they find their way, sometimes for thousands of miles, over wholly unknown stretches remains as much of a mystery as the epic migrations of fish. The author does not enter deeply into any single department of animal navigation, but his descriptions are excellent, as is his account of the many fascinating experiments which naturalists have designed to discover the markers and signposts of the animal world. A most attractive little monograph.

THE HISTORY OF MATHEMATICS, by Joseph E. Hofmann. Philosophical Library ($4.75). This volume offers a translation of a sound and perceptive history of mathematics (from the ancients to Fermat and Descartes), the original German edition of which was published in 1953 and was reviewed in *Scientific American.* But one further mathematical point deserves mention. The original edition, a larger paperbound book with a comprehensive index, cost 60 cents; the present volume, with all valuable tables, bibliographies and subject index omitted, costs eight times as much.

Notes

TRANQUILIZING DRUGS, edited by Harold E. Himwich. American Association for the Advancement of Science ($5). Papers on pharmacological and therapeutic aspects of various tranquilizers, presented at a symposium held in Atlanta in 1955.

DICTIONARY OF MICROBIOLOGY, by Morris B. Jacobs, Maurice J. Gerstein and William G. Walter. D. Van Nostrand Company, Inc. ($6.75). A practical reference volume which defines terms current in microbiology and certain related terms of bacteriology, mycology, virology, cytology, immunology, immunochemistry, serology and microscopy.

A GLOSSARY OF MYCOLOGY, by Walter H. Snell and Esther A. Dick. Harvard University Press ($5). A new dictionary of some 7,000 terms peculiar to mycology or generally useful to students of the subject.

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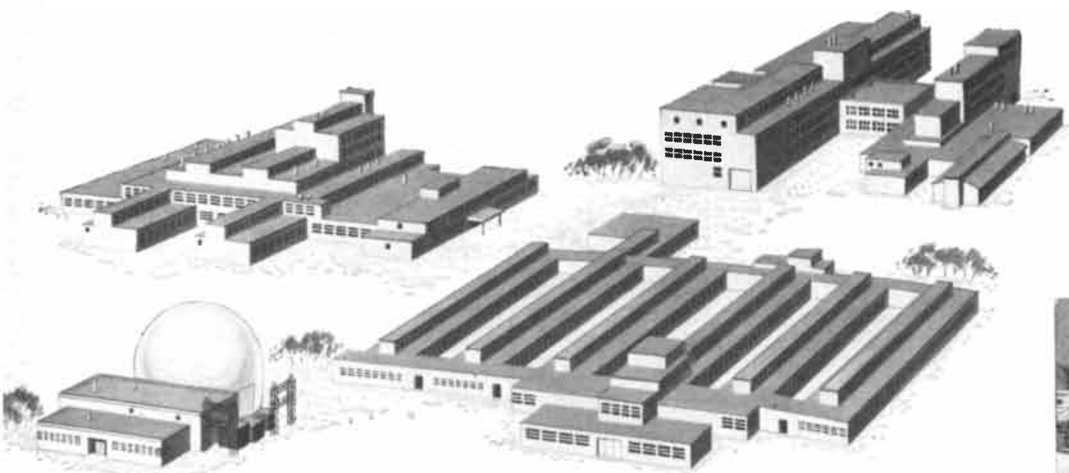

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