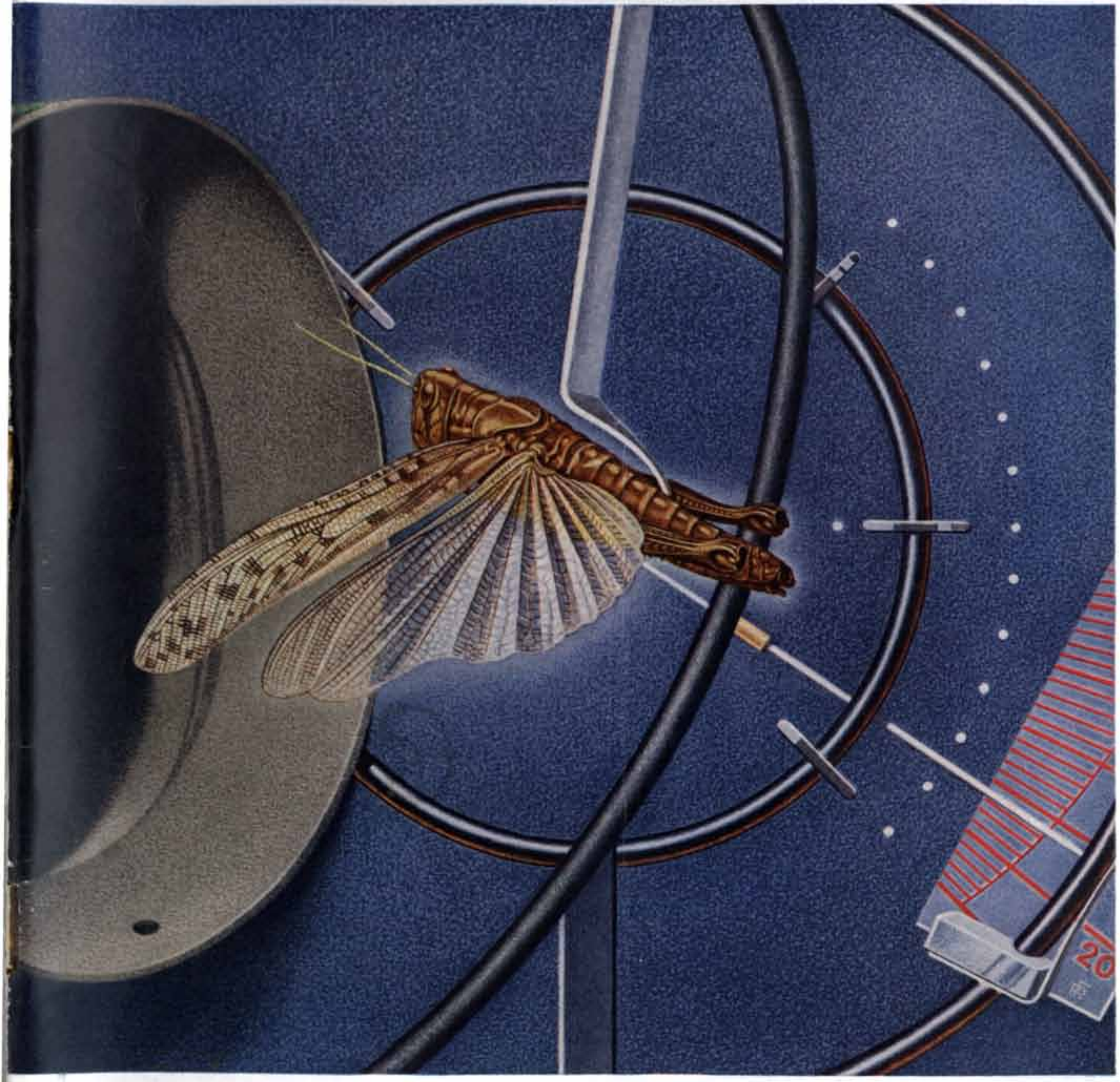
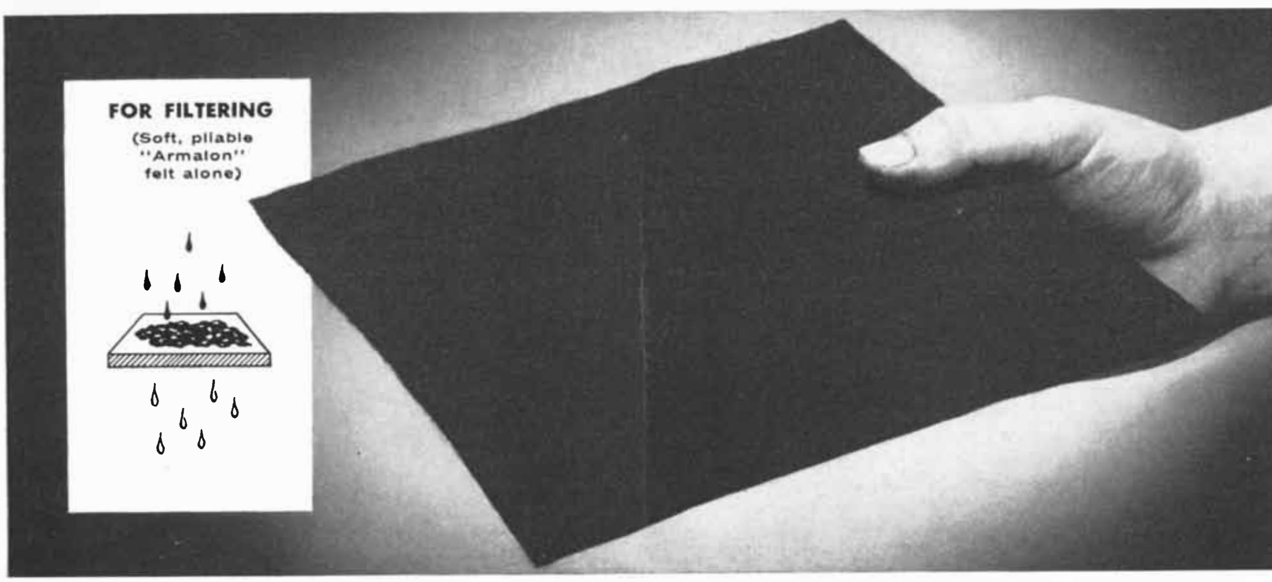
SCIENTIFIC AMERICAN



LOCUST AND WIND TUNNEL

FIFTY CENTS

March 1956



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The gears and cams used in this taximeter bear against steel pins and shafts. Steel castings won't hold up—as steel wears on steel, shafts are worn, holes elongated, and tolerances expanded to the point that the meter operates erratically.

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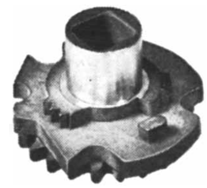
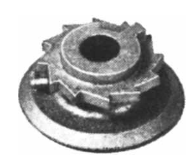


FLAG INDEXING CAM; one of the most complicated single-cast parts ever produced . . . it has lobes, teeth, ratchets, cams, a square tapered hole, and a disengaging stop. Steel could never be cast in such a complication of design, and brass is too soft to take the beating. The tapered socket measures .628″ with a tolerance of —0.005″ and +0.00″.

BRAKE ACTUATING CAM; a zinc alloy formerly used for this part would not stand up under the terrific amount of wear imposed . . . it would change size as much as 1/16″, break, and come off the shaft. The zinc alloy was replaced by a beryllium copper casting, which, with simple heat treatment, registers a Rockwell of C-37 to C-43, more than enough to withstand the rigors of operational stress.



RATCHET HUB; used to operate the "extras" tabulation, which is actuated by a lever binding against the ratchet periphery of this part. The center hole of this part must fit over a steel stud in what amounts to a lap fit with a minimum acceptable tolerance of .001″. It was impossible to maintain this tolerance with steel, and machining costs were out of proportion. The part is now cast of "BERYLCO" brand beryllium copper to specifications which require a hub of .250″ with tolerances of —0.00″ and +.002″.

RETURN LEVER CAM; has an outside diameter of 1.565″, pitch of 16, contains 23 teeth with a circular pitch of .1963″. The depth of the teeth is .1348″, and the thickness of the teeth .098″. Used to reset the dollar and cents scale, this cam is under very high spring tension at all times, and nothing but the most hardened material could withstand this duty.

Established 1845 **SCIENTIFIC AMERICAN** March, 1956 Volume 194 Number 3

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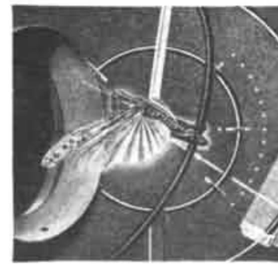

THE COVER

The painting on the cover shows a locust flying against the air stream of a wind tunnel (*see page 116*). The insect is suspended from a streamlined metal rod attached to its body by means of a suction cup. The other end of the rod (*not shown*) is fastened to a balance which measures the lift and thrust developed by the insect. In the lower right-hand corner of the painting can be seen a scale for measuring the angle between the insect's body and the air stream. The animal pictured here is the four-winged desert locust *Schistocerca gregaria*. The specimen is from The Academy of Natural Sciences of Philadelphia.

THE ILLUSTRATIONS

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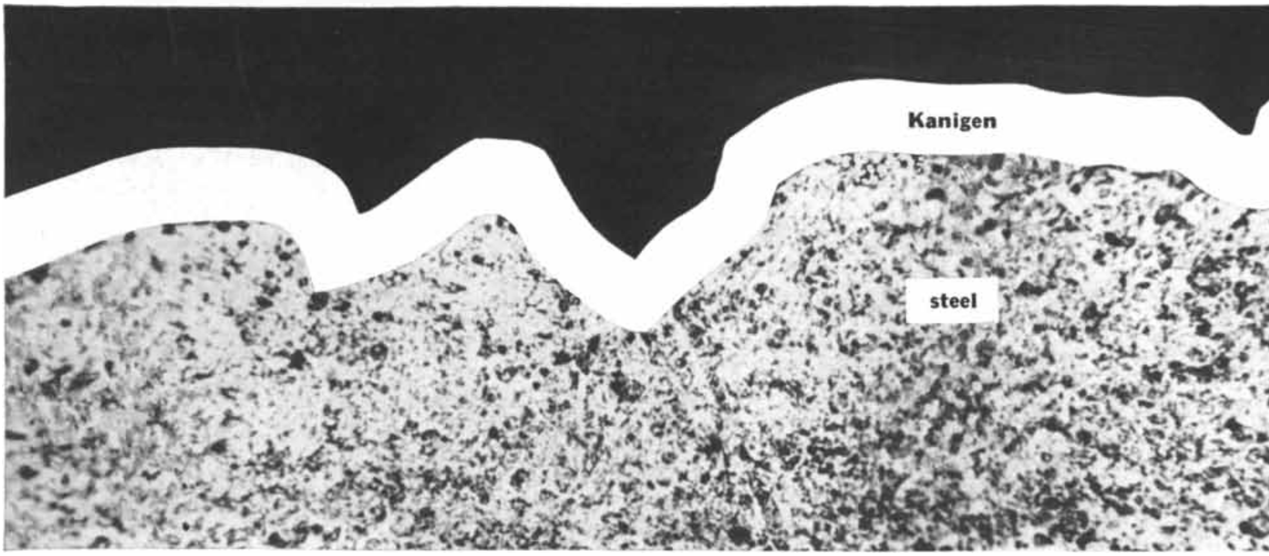

photomicrograph showing uniformity of Kanigen coating over steel (150x).

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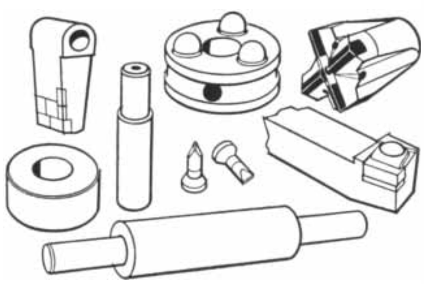

LETTERS

Sirs:

In his very interesting article "Translation by Machine" [SCIENTIFIC AMERICAN, January] William N. Locke cites the case of a paper by A. G. Lunts, published in Russian in 1950, ignorance of which is estimated to have cost American companies $200,000. He does not mention that *Mathematical Reviews* for September, 1950, contained a 15-line review in English. The review was a concise review of the three-page article; it occurred in the algebra section of a mathematics periodical; the author's name was transliterated Lunc, but the relation to electrical networks was explained. Does not the case suggest more the need for the application of machines to the bibliographic problems of cross-referencing publications rather than the more fascinating application to the problem of translation?

EDWARD H. CUTLER

Department of Mathematics
and Astronomy
College of Arts and Science
Lehigh University
Bethlehem, Pa.

Sirs:

A translation machine is a theme of great interest. It seems to me, however, that the procedure would soon run up against inherent limitations. It would certainly emerge with an answer that would be a word in its English memory; but would that word accurately represent the word in the original, as used in the phrase, quite apart from considerations of content and relevance, let alone style? Again, how is a root to be recognized even in so closely related a language as Spanish, when the root vowel often changes, as in the simple word "to sleep" (*dormir*, *duerme*)? In a language like Polish, the roots of large numbers of words undergo fundamental changes in both vowel and consonant components. With an agglutinative language like Hungarian, machine translation might seem to have an easier task; yet if we take such a word as *kivilagitas* (illumination), how is the machine to decide where to break it up, and know that the basic element is *vilag* (light) rather than *kivi* (a short form of the verb *kivivni*, "to achieve"), or *agit*, which is not a Hungarian word at all? I leave the machine to ponder over the fact that *vilag* itself has the additional meaning "world," and to find some way of distinguishing the two. As to what would happen with Chinese and Japanese, those familiar with the problems involved in combining the characters can only shudder at the results the mechanical translator might grind out.

Let us now put the shoe on the other foot for an instant, and imagine our machine rendering the English word "ring" into French. If it is a shape, shall it be *anneau*, *bague*, *maille*, *segment*, *rond*, *collier*, *enceinte* or *arène*, or one of a dozen others? Or if it is a sound, shall it be *son*, *tintement* or *coup de téléphone?* If the answer is to be that we must go by the context, we lose most of the advantages promised; and if the machine is set to give *anneau*, and let the reader supply the shade of meaning and the area of signification, I see nothing but confusion resulting.

It would also be advisable to envisage the opposite way out: namely, educating (I was tempted to say humanizing) the scientists. . . .

HENRY F. MINS

Clinton, N. J.

Sirs:

Professor Cutler is right. My example does show the need for machines to keep the bibliographies of specialized fields up to date. Both this and language translation are special cases of data processing, a field in which great strides are being made with new equipment com-

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ing onto the market daily. The big question mark is how to handle data expressed in language. Languages are codes. Machines can process these codes only when all the rules governing them have been made explicit. Until then we can neither make satisfactory bibliographies nor translate languages by machine.

My example was not intended to point up ignorance of the very fine coverage of Russian mathematics by *Mathematical Reviews*; rather, I think it shows that if you know no Russian an abstract doesn't help much. It is simply impossible for abstracters to say which article will be vital for somebody. Yet unless you know that a paper or a book is vital, you can't afford the cost of translation. So what we need is fast, inexpensive translations. They will remove the psychological barrier that faces anyone when he sees that an abstracted paper is in a language he can't even begin to read.

Mr. Mins touches on some of the thorniest problems of translation by machine. These questions of changing roots, compound words, and the many possible meanings of any one word have excited the interest of linguists since the first suggestion of the application of machines to the translation of human languages. The present state of the thinking will be found in papers in the journal *Mechanical Translation* and in the book, *Machine Translation of Languages*. Briefly, it has been proposed that all forms of the roots of words be incorporated into the machine memory in their proper alphabetical place. The same applies to irregular forms of any kind, verb and noun endings, contractions, in short, to all idiomatic constructions. Regular forms like the *-ed* of the English past participle or the *-s* of plural nouns will probably be identified in a procedure similar to that worked out for Russian endings by Anthony Oettinger to get the grammatical meaning, while the roots are looked up in the memory for the lexical meaning.

An elegant procedure for analyzing German compound words has been worked out by Erwin Reifler. He has recently built a simple computer to test his method of analysis. If satisfactory for German it seems likely to work also for the agglutinative languages.

As for the many meanings one word in English may have in a foreign language or *vice versa*, this is the crucial problem. The only indication we can have as to which meaning of a word is intended in a given case is the context, context in the larger sense including both the topic under discussion and the adjoining words. Looking at Mr. Mins's French translations of the word "ring," it is obvious that at least one, *arène*, will scarcely if ever appear in technical material (to which we are limiting our efforts for the present), and that others will be more or less likely according to whether the paper is in physics, mechanical engineering or some other field. It is perfectly possible to arrange the machine memory so that when a physics paper is being translated only the meaning or meanings used in physics are printed. The reader might still have to choose among several alternatives on the basis of context except for the fact that the machine can probably be instructed to make this choice, as is shown by the work of Victor H. Yngve.

As a teacher of modern languages I am happy to applaud Mr. Mins's suggestion that American scientists learn three or four key languages.

WILLIAM N. LOCKE

Department of Modern Languages
Massachusetts Institute of Technology
Cambridge, Mass.

Sirs:

In your issue of December, 1955, a letter by Willard Hatch takes issue with the emphasis I laid upon Maupertuis's discovery of the principle of least action in my article in your October issue. I pass over the first paragraph of the letter, which appears merely to restate matters I had related, and come to the second, the gist of which is that Ernst Mach, in his *Science of Mechanics*, expressed a low opinion of Maupertuis's originality and clarity of mind in the enunciation of this principle, which received a rigorous form only when reworked by Euler. Part of Mr. Hatch's conclusion may be due to the fact that he used the English translation of Mach's *Science of Mechanics*, which is quite inaccurate; it translates "*Weg eines Körpers*" as "the space described," for example, instead of the proper meaning "path." But aside from that, one must remember that Mach's criticism was written in 1883 and never modified in later editions, although, as I have elsewhere pointed out, the advent of the quantum theory considerably altered the point of view of physicists on such matters. But I am no physicist, and it will be better to allow the physicists themselves to argue this matter out. I would only like to emphasize that Jerome Fee, in the article to which I referred interested readers, fully and I think adequately disposed of this criticism of

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Ernst Mach's, in the following passage:

"A more serious criticism of Maupertuis is that even apart from metaphysics, he had no adequate conception of his own discovery, and that his applications of it were merely trivial. There is, apparently, only one book in English (a translation from the German) which gives an account of the three problems which Maupertuis worked out to illustrate his principle. We refer to Mach's classical *Science of Mechanics*. It is far better, if one can do so, to read Maupertuis's own words which give in concise, lucid style his applications of least action to inelastic impact, elastic impact, and the principle of the lever.

"If Maupertuis's works are not available, however, Mach's book gives a fairly good outline of these three cases. His conclusions, nevertheless, as to their importance and as to the importance of least action and Maupertuis's contribution thereto, are entirely wrong. They will ultimately be recognized as the most glaring imperfections in a book which betrays unexpected limitations in more than one respect.

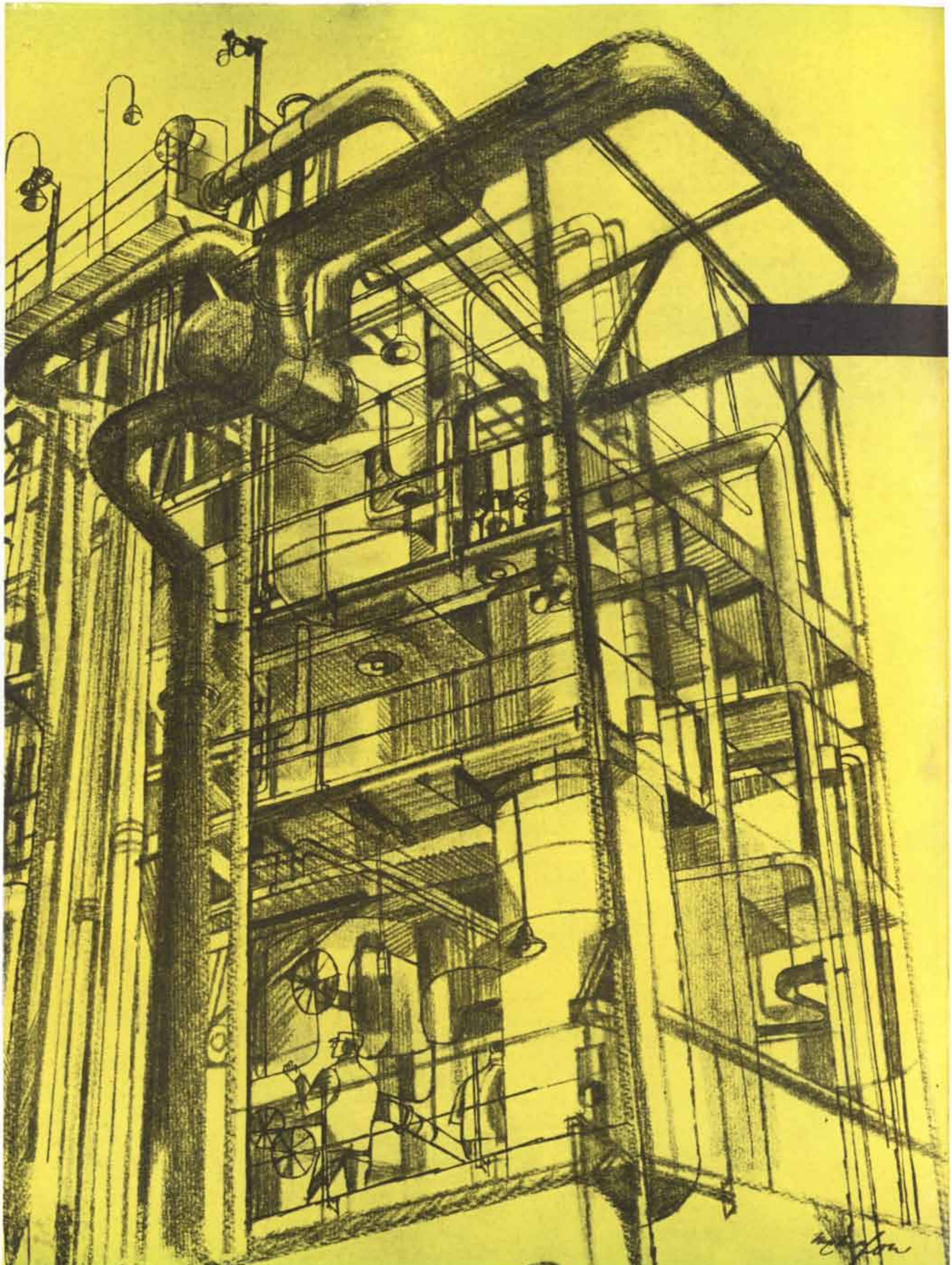
"To show how far Mach was from grasping this particular subject, he attempts to belittle the importance of least action by referring to another principle of mechanics which is equally powerful; namely, Hamilton's principle. This principle well deserves to be called after the great Irish mathematician, but it is an 'action' principle. 'Hamilton's function' has the dimensions: energy multiplied by time. Hence Mach has merely shown how the principle of least action was in later years to be recast into another and perhaps more significant form."

I strongly recommend to readers who are interested in the principle of least action that they read the brilliant article by Fee in its entirety.

While writing to discuss this point, let me take the opportunity of correcting an error in my article. I described Maupertuis's expedition to Lapland to procure evidence regarding the flattening of the earth toward the poles, a test of Newton's theory, and inadvertently said "by measuring a degree of longitude." What I had in mind was of course the measurement of a degree along the meridian of longitude, which would consequently be a degree of latitude. Measuring a degree of longitude would have succeeded only in showing that the meridians converge toward the pole!

BENTLEY GLASS

The Johns Hopkins University
Baltimore, Md.



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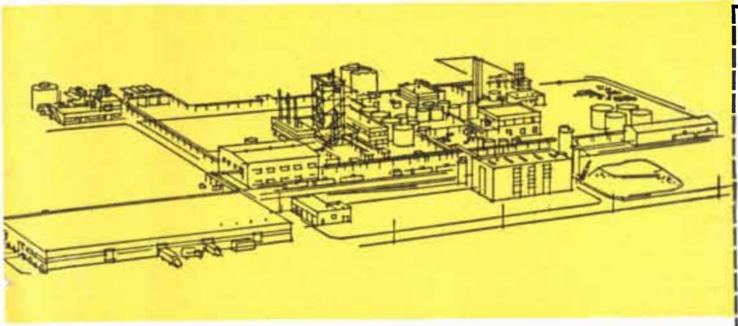

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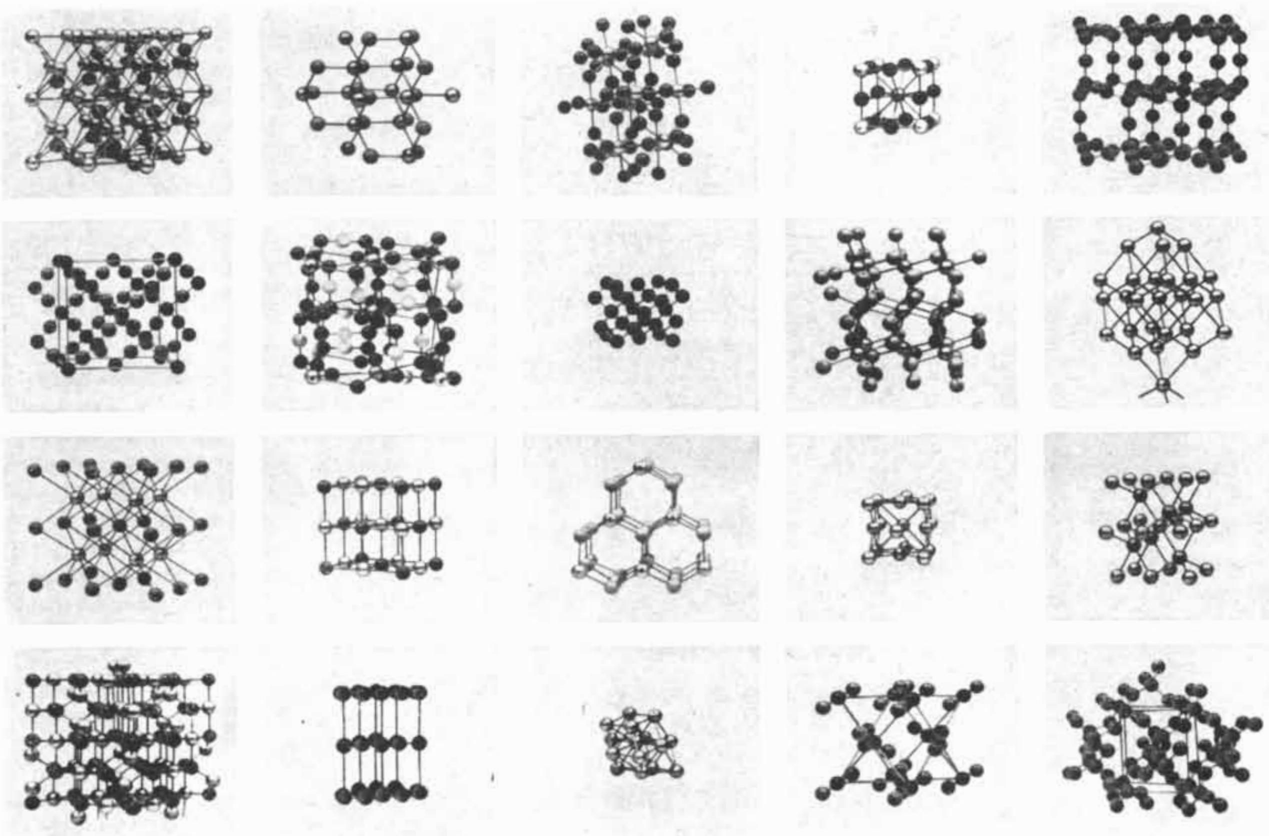
50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

MARCH, 1906: "Henryk Arctowski, a member of the Belgian Antarctic expedition, is planning to go to the South Pole in an automobile. He declares that one may go by ship to the lower end of Ross Sea, at 78 degrees latitude, to the foot of Mount Erebus and Mount Terror, proceeding thence to the point already reached by Scott. This explorer was forced to proceed on foot for five months. He could have continued on his way over the icy plain, but did not have sufficient provisions, and was compelled to retrace his steps. It is now a question, therefore, of finding out how one can accomplish this journey in an automobile, and advance even farther. The distance from Mounts Erebus and Terror to the South Pole is about 805 miles. Mr. Arctowski believes that he can accomplish this distance in three trips. A first automobile will depart loaded with provisions, and will arrive at the first station. A second will be dispatched to restock the first with gasoline, and will return to the point of departure. A third automobile, making two trips, will restock the first automobile at the second station, permitting it to proceed to the actual Pole. Returning, one automobile will be abandoned at the Pole, and another on the way. They will cover six miles an hour, or 12 at the most, and will be specially constructed, after experimenting on the Alpine glaciers, for instance on the Aletsch Glacier in Switzerland. The expedition will depart in August, 1907, for the Antarctic regions."

"According to *l'Illustration* (Paris) scientific men agree to-day in admitting that water *physically* pure, seen in mass, is sky blue. This color is that taken by the white light of the sun when absorbed by the water. The water at present acknowledged to be the bluest is that of the Sargasso Sea, between the Cape Verde Islands and the Antilles. The water of the Mediterranean off the French coast and around Capri is bluer than that of Lake Léman, much less blue itself than that of the lakes of Kandersteg and Arolla in Switzerland. According to



Crystal structure models. Top row, left to right: cuprite, zincblende, rutile, perovskite, tridymite. Second row: cristobalite, potassium dihydrogen phosphate, diamond, pyrites, arsenic. Third row: caesium chloride, sodium chloride, wurtzite, copper, niccolite. Fourth row: spinel, graphite, beryllium, carbon dioxide, alpha-quartz.

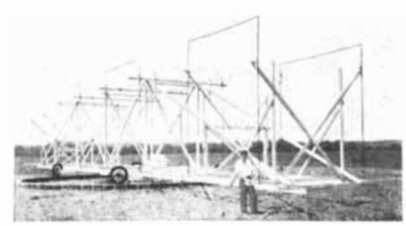
FROM ATOMS TO STARS

Research at Bell Telephone Laboratories ranges from the ultimate structure of solids to the radio signals from outer space. Radio interference research created the new science of radio astronomy; research in solids produced the transistor and the Bell Solar Battery.

Between atoms and stars lie great areas of effort and achievement in physics, electronics, metallurgy, chemistry and biology. Mechanical engineers visualize and design new devices. Mathematicians foreshadow new communications techniques.

Despite the diversity of their talents, Bell Laboratories scientists and engineers have much in common. A habit of teamwork channels these talents into great communications advances. These men have developed the world's finest telephone system. In doing so, many have become leaders in their fields. Opportunities for achievement await properly qualified scientists and engineers at Bell Telephone Laboratories.

Models of the atomic patterns in solids help Bell Laboratories scientists visualize their electrical behavior.



Directional antenna used by Karl G. Jansky in discovery of stellar radio signals at Bell Telephone Laboratories in 1932.

BELL TELEPHONE LABORATORIES

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Forel's experiments, the matter in solution should be the predominant cause of the modification of color. The Belgian, Prof. Spring, who has been a long time studying this delicate question, has just communicated to the Academy of Sciences at Brussels some interesting figures. Six feet of pure water containing a millionth part of ferric hydrate appears brown; a ten-millionth part is sufficient to make the water green; at less than a twenty-millionth part it remains blue."

"A curious effect was noticed in connection with a kinetograph view which was taken in Germany not long ago. It was obtained at the time of the visit of the King of Spain to Berlin and represented the entrance of the procession into the city. The horse guards led off, then a line of carriages and lastly a line of mounted cavaliers. What was surprising about this view was that while the carriages moved in the line of march as they should do, the wheels appeared to revolve slowly in the contrary direction. This phenomenon is easily explained, although at first it puzzled nearly everyone. To take the views we photograph the objects successively within at least one tenth of a second. According to the relative speed of the wheel and the apparatus, we may find that the successive spokes have a slight advance or lag relative to the position of the first one and give the illusion that the wheel is turning forward or back, as the case may be."

SCIENTIFIC AMERICAN

MARCH, 1856: "The next annual meeting of the American Association for the Advancement of Science will be held in the city of Albany, N. Y., in the month of August next. We understand that invitations have been given to a number of the *savans* of Europe to be present on the occasion, and that some of these have been accepted. Some of the agents of the Atlantic steamers have offered a free passage to certain of these *savans*, and it is believed that the Committee of Arrangements, at Albany, will enable some of them to visit our country without its costing them anything. This is very gratifying. The Hon. Jas. S. Wadsworth has subscribed $500 to defray Liebig's expenses, and others in Albany have also subscribed liberally. The State Museum of Natural History is then to be inaugurated, and Wm. H. Seward is to deliver a lecture

on the occasion. This, we think, is a wrong arrangement. Some well-known naturalist, like Agassiz, should have been chosen to do this."

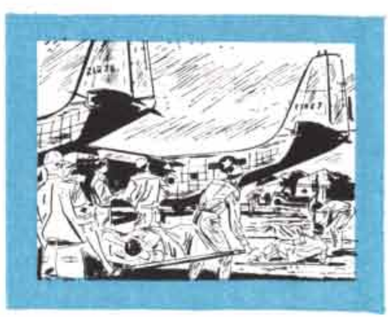
"The British Government has granted a pension of £200 per annum to Francis Petit Smith, in consideration of the efforts made by him and the expense he incurred in the introduction of the screw propeller into the British Navy and the mercantile marine. The screw has completely superseded the paddle wheel in the Navy, and the whole war fleet of that nation is now almost exclusively composed of screw steamers."

"In a letter from the Crimea a soldier makes the following comments, among others, about the new Enfield rifle. 'There is an objection on the part of the men,' he notes, 'to the new plan, copied from the French (and Russians) of fixing the bayonet by a movable ring, instead of retaining the spring of the Minié rifle. There is an advantage in retaining the spring, and it is this: Every officer of experience knows the thirst produced by the saltpeter and sulfur of the gunpowder getting into the mouth each time a man bites the cartridge. Well, Surgeon Tweeddale devised a very simple remedy. The end of the bayonet is flattened out, and Dr. Tweeddale has a slit filed down in this portion of the spring. By pressing the waste end of the cartridge against this slit with the thumb, the paper is at once torn off and the cartridge is ready for use.' "

"The custom of dropping a ball accurately at a given time was adopted and has been carried out at the Royal Observatory at Greenwich, London, for many years, for the purpose of enabling outward bound shipmasters to determine the error of their chronometers before leaving port. Within two or three years the American method of chronographic observation has been introduced at Greenwich, and in connection with this the great clock of the Observatory has been made to drop the ball automatically by a telegraphic signal. No such apparatus exists at present in America, and the only approach to it is the ball upon the U. S. Naval Observatory at Washington, which is thrown down by hand at the word of command. In view of this Prof. Bache, of the Coast Survey, and Prof. Gould, of the Dudley Observatory, at Albany, N. Y., have sent a message to the Mayor expressing a desire to supply New York with time, which they offer to be accurate to the tenth of a second."

THROUGH THE SCHOOL OF HARD KNOCKS WITH FLYING COLORS!

The Fairchild C-123 was especially designed for landings and take-offs on rough, unprepared fields.



Litter patients, airborne troops or almost 10 tons of bulk equipment may be airlifted by the C-123. A built-in ramp facilitates *quick loading and unloading of cargo and troops.*

During "Operation Shakedown", the C-123 was subjected to 500 hours of rugged duty under all operational conditions.

FAIRCHILD C-123 PASSES OPERATIONAL SUITABILITY TESTS

Now being subjected to rugged tests for the U. S. Air Force, the Fairchild C-123 Assault Transport has proved it can withstand the rigors of any combat airlift mission and win an "A" for top performance!

Shown above is an actual photograph of a C-123 making a short field landing downwind over a 50-foot obstacle on a sandy, deeply rutted strip at Eglin Air Force Base. During other tests the C-123 was flown in simulated front line combat airlift missions and proved its durability by landing and taking off on extra rough terrain in the shortest possible distance.

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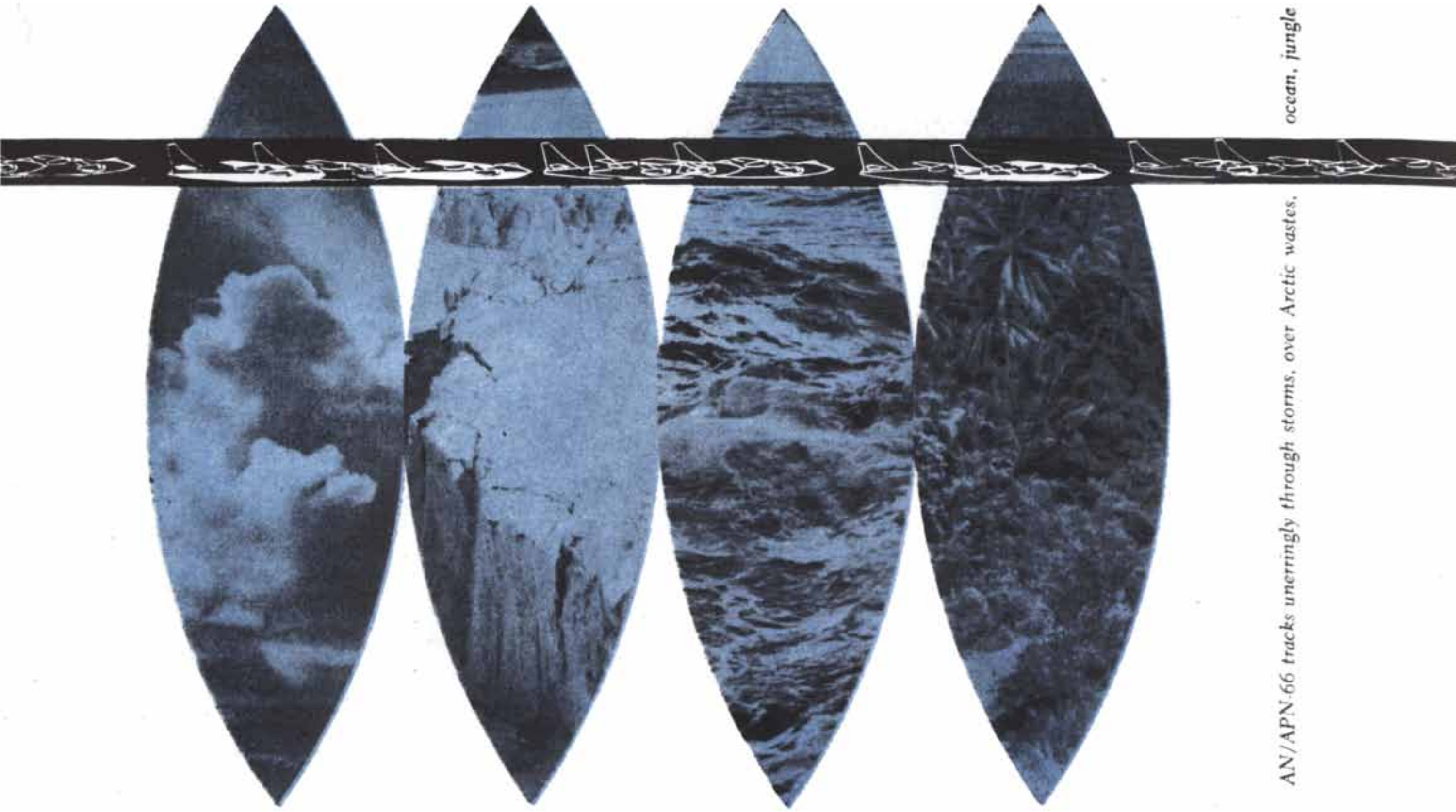
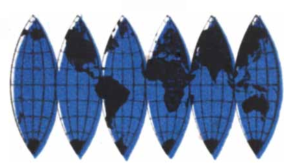


AN/APN-66 tracks unerringly through storms, over Arctic wastes, ocean, jungle

planes that need never get lost
—anywhere



GPL has produced the most advanced automatic air navigation system known to exist.

It guides an airplane to its destination *under any conceivable conditions.* It is not in the experimental stage; the system has been in production more than a year, flown millions of operational miles. It is completely self-contained, needs no ground guidance, no search radar, no optical observation. It works equally well anywhere in the world. Its operation is virtually instantaneous.

This GPL System is called AN/APN-66.

Fly over empty seas, barren deserts, featureless ice fields, mountain ranges. Fly at the highest altitudes aircraft have reached or skim the surface of the sea. Fly arrow straight or tossed like a leaf in a hurricane. It makes no difference. Snow, fog, electrical interference, make no difference. AN/APN-66 always knows exactly where a plane has been, where it is, and where it must go to reach its goal.

The military application of a system of such capability is far reaching. To achieve it, GPL mobilized scientific manpower and facilities in a large-scale emergency program in cooperation with the Air Force. Four other GPE companies also took part. Even so, development of AN/APN-66 took eight years, for it required a seemingly impossible engineering achievement: the harnessing of the physical phenomenon known as "Doppler-effect."

The "Doppler-effect" is the shift in the frequency of waves, sound or electrical, transmitted from a moving object to a stationary observer. It is most familiar as the shift in the pitch of a train whistle as it approaches and passes. AN/APN-66 measures a similar shift in the frequency of radar waves it bounces off the surface of the earth below. From the difference in frequency between the original wave and its echo the system computes the speed and direction of the plane's movement in relation to the ground. Electronic computers use this data to keep continual track of the plane's position by what is, in effect, automatic, instantaneous and highly precise dead reckoning.

This outstanding product of GPL's engineering skills and creativity—and its variations, the AN/APN-82 and AN/APN-89—are in use in a wide range of service planes—bombers, patrol craft, transports, mine layers, hurricane hunters. Every day the systems go into more aircraft as standard equipment. When put to civilian use, they will guide air liners to the remote corners of the world with equal accuracy.

While you may have no need for a navigation system, you may very well have need of the engineering skills and advanced technological resources that made AN/APN-66 possible. These are at your service.

To learn how GPL products and engineering skills can help you, write to:

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I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	
●●●	●●	●●	□●●	●●	●●●		●●	●●●	●●	●●	●●	●●●	Precision Mechanics, Optical Devices, Ceramics
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●●●			●●●	●●●	●●●	●●●				●●●		●●●	SYSTEMS ENGINEERING


Librascope Desk-Size Computer


Link Aviation F-89D Jet Simulator


GPL Industrial-Institutional TV System


Griscom-Russell Shipboard Distilling Plant


Askania Electro-Jet Power Package

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In Systems Engineering, advanced capacities and resources are prerequisite. Yet, no matter how highly advanced, they are insufficient if limited to a few areas. And beyond that, success requires the application of such *balanced competences* at every stage—beginning with research and extending all the way through development, production, and final testing.

The following basic characteristics and methods of operation of the GPE Companies explain GPE successes in systems work:

- *the exceptional engineering acumen of more than 2500 GPE scientists, engineers and technicians working in depth in the wide range of advanced capacities indicated in the chart above;*
- *the extensive research, development, manufacturing and testing resources of the GPE Companies;*
- *the GPE operating policy, Coordinated Precision Technology, which inter-relates all relevant GPE engineering, research, and production skills and resources;*
- *unremitting insistence on highest quality on the part of every GPE Company, every step of the way.*

No GPE Company is limited by the boundaries of its own specialties. Behind each engineering group working on a specific problem in one GPE company stands the whole group of GPE scientists, engineers and technicians with the answers—or the knowledge that will find the answers—to questions underlying and related to that problem.

To the customers of GPE Companies this means that the concept and development of equipment, components and systems are not restricted or distorted by traditional allegiance to specific competences. The five systems illustrated, while products of different GPE companies, are all examples of the consistent application of balanced competences, achieved through GPE coordination.

For brochure describing GPE Coordinated Precision Technology and the work of the GPE Companies, or help on a specific problem, write: General Precision Equipment Corporation, 92 Gold Street, New York 38.

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THE AUTHORS

STANLEY W. DAVIS ("Stress in Combat") is a research leader at the Operations Research Office of the Johns Hopkins University. He was born in Elizabeth, N. J., in 1920, graduated from Cornell University in 1947 and took a Ph.D. in industrial psychology there in 1951. His thesis was on the use of auditory flutter fusion as a measure of fatigue. The Operations Research Office, which he joined as operations analyst, is under contract with the Army to provide military commanders with a scientific basis for making decisions. It was in 1952 that it sent its investigators to Korea, in a team that also included members from the Army and Navy. Davis lives in Silver Spring, Md., and is president of his local Parent-Teachers Association.

JOHANNES IVERSEN ("Forest Clearance in the Stone Age") is head of the Paleobotanical Laboratory of the Geological Survey of Denmark and lecturer at the University of Copenhagen. He took a Ph.D. in biology at the University of Copenhagen in 1936. His principal research has been in plant ecology and vegetational history. While tracing the factors governing the vegetational succession of the past as they are reflected in pollen records, he came upon evidence of large-scale clearances in the Danish forests of Neolithic times. At present he is in the U. S. as a guest of Yale University on a Rockefeller Foundation grant.

ERNEST F. GALE ("Experiments in Protein Synthesis") is director of the Medical Research Council unit for chemical microbiology and a university reader in microbiology at the University of Cambridge. He attended Weston-super-Mare Grammar School and St. John's College at Cambridge. At the University he took an Sc.D. and a Ph.D. and conducted his early research under Sir F. Gowland Hopkins and Marjory Stephenson. His present work on protein synthesis grew out of observations he made in 1945 on the effect of penicillin on certain bacteria. He has been on four visits to the U. S., most recently, in 1955, to deliver the Harvey lecture at the New York Academy of Medicine.

JULIAN HUXLEY ("World Population"), as a member of an illustrious family of scientists and writers, has done

a good deal of writing himself. His previous appearance in SCIENTIFIC AMERICAN was as the reviewer of George Gaylord Simpson's *Life of the Past* in the issue of August, 1953. He is most widely known for his attempts to bring biological issues before the public, not only in his own books but also in volumes written in collaboration with J. B. S. Haldane and H. G. Wells. Huxley was Director General of UNESCO in 1947-1948. He is frequently in the U. S., and once taught at the Rice Institute in Texas (from 1912 to 1916). Much later, in 1943, he expressed his enthusiasm for an American experiment in *TVA: Adventure in Planning*. In *From an Antique Land*, which appeared in 1954, he told of impressions gathered in the Middle East.

WILLIAM A. BAUM ("Electronic Photography of Stars") is an astronomer at the Mount Wilson and Palomar Observatories, which are operated jointly by the Carnegie Institution of Washington and the California Institute of Technology. He graduated from the University of Rochester in 1943 and took a Ph.D. at Cal Tech in 1950. "Ever since I was a small boy," he writes, "I have had a burning desire to explore the frontiers of space." He has been involved in photographing the ultraviolet spectrum of the sun with instruments carried in high-altitude rockets, in measuring the spectral transparency of smog and in establishing standards for measuring the light of faint stars. His present research is in the latter field. It involves literally counting the individual photons from faint stars as they are received by the 200-inch telescope. The ultimate purpose of these observations is to determine the distances of remote galaxies.

H. B. G. CASIMIR, O. R. FRISCH, J. LINDHARD *et al.* ("Jocular Physics") are physicists and friends of Denmark's Niels Bohr. Their affectionate tributes to Bohr on his 70th birthday take the form of playful spoofery of physics today; some of the pieces have been delivered as lectures to their colleagues in Europe. Casimir, director of the physics laboratory of the electrical and electronics firm of Philips at Eindhoven in the Netherlands, was an assistant to Bohr in Copenhagen from 1928 to 1931. He was born in The Hague and took his doctorate at the University of Leiden in 1931, becoming professor of physics there in 1933. He has been with Philips since 1942. Frisch is Jacksonian Professor of Natural Philosophy at the University of Cambridge and head of the nuclear physics section at the Caven-

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dish Laboratory. He was brought up in Vienna, where he took his Ph.D. It was Frisch who, with Lise Meitner, first definitely identified the phenomenon of uranium fission. Frisch later worked at the Los Alamos Scientific Laboratories. Lindhard is an assistant to Bohr at the University Institute for Theoretical Physics in Copenhagen.

MORRIS KLINE ("The Straight Line"), a mathematician and writer, wrote the article on "Projective Geometry" in SCIENTIFIC AMERICAN for January, 1955, and reviewed George Polya's *Mathematics and Plausible Reasoning* in the March, 1955, issue. He is professor of mathematics and director of electromagnetic research in the Institute of Mathematical Sciences at New York University. His *Mathematics in Western Culture*, a book for the general reader, appeared in 1953.

TORKEL WEIS-FOGH ("The Flight of Locusts") is a Danish biologist who is now in the department of zoology at the University of Cambridge in England. He took an M.S. and a Ph.D. in zoology at the University of Copenhagen in 1947 and 1952, respectively, after receiving the University's gold medal in 1944 for work in soil biology. He started as an assistant to August Krogh in the study of insect flight which he reports here, and after Krogh died in 1949 Weis-Fogh took over the leadership of the project. His salary, he notes, was paid by the Anti-Locust Research Center in London. From 1953 until this year he was lecturer at the University of Copenhagen, spending part of his time at the University of Cambridge as a fellow of the Rockefeller Foundation.

HARRISON BROWN, who reviews *Earth in Upheaval*, the latest book by Immanuel Velikovsky, is professor of geochemistry at the California Institute of Technology. He was born at Sheridan, Wyo., graduated from the University of California in 1938, and took a Ph.D. in chemistry at the Johns Hopkins University in 1941. After spending a year teaching at Johns Hopkins and a year in research on the plutonium project at the University of Chicago, he joined the Clinton Laboratories at Oak Ridge, Tenn., where for three years he was assistant director of the chemical division. He returned to teaching at the University of Chicago Institute for Nuclear Studies in 1946. Five years later he transferred to Cal Tech. In 1952 Brown received the Award in Pure Chemistry of the American Chemical Society.

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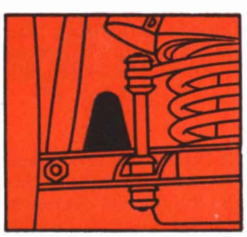

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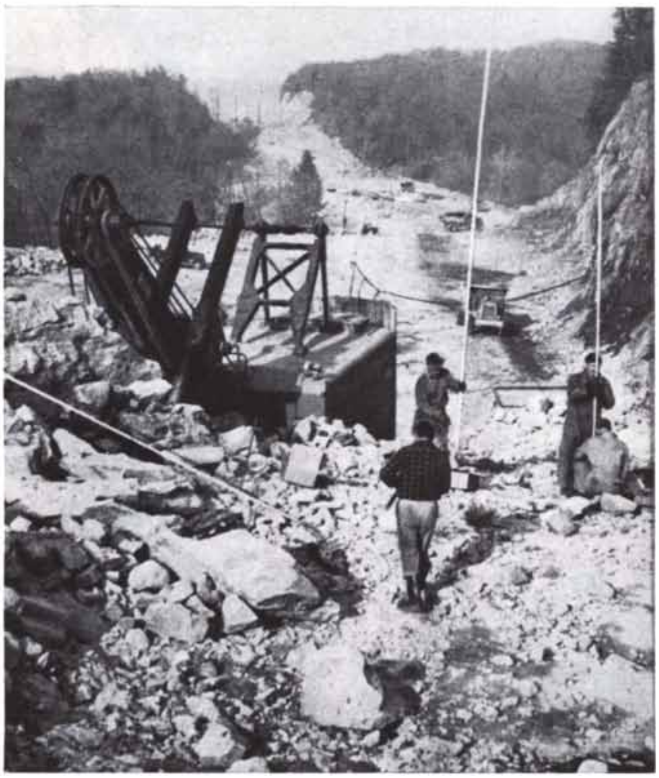
Life

on the Chemical Newsfront



(Above) **NORMAL GROWTH** is not possible without Folic Acid, an essential factor in the formation not only of red blood cells but all body cells. Everyone needs it daily. During periods of rapid growth, as in infancy and pregnancy, there is an increased need for this rare vitamin. Recognition of Folic Acid's importance has led to its wide use in B-complex and multivitamin preparations. Recently Cyanamid introduced to the drug trade an improved product containing a minimum of 93% anhydrous Folic Acid, the highest potency yet attained commercially. **(Fine Chemicals Division)**

(Left) **NEW HIGHS IN HIGHWAY CONSTRUCTION** are forecast this year, with contract volume expected to rise 17% to $2½-billion. The spread of highways and superhighways over every type of terrain presents titanic earth-moving tasks. In leveling hills to smooth the motorist's way, and quarrying rock for paving materials, Cyanamid explosives and blasting supplies will play a big part. Among Cyanamid products serving contractors are high explosives and precisely timed electric blasting caps that help insure good breakage and reliable results. **(Organic Chemicals Division)**

A UNIQUE NEW SYSTEMIC HERBICIDE, Amino Triazole, selectively kills a number of perennial weeds. While most herbicides kill by contact, Amino Triazole enters the sap system and spreads to all parts of the plant. It suppresses growth and unbalances the chlorophyll-producing mechanism, ultimately killing roots. Canadian thistle is among plants susceptible to Amino Triazole. *Photo left* shows typical whitening or chlorosis of new growth one week after spraying. *Photo right* shows how Amino Triazole is translocated into roots; this stunted white plant was sent up from root system of parent plant that was sprayed. Among other noxious perennials that can be controlled are quack grass, nut grass, ash, scrub oak, poison ivy, poison oak, rushes, and Russian knapweed. **(Agricultural Chemicals Division)**

Women's work makes chemical markets

(Above) **HER NEW CLOTHESLINE IS PAPER!** Plymouth Cordage Company, Plymouth, Mass., now produces Fibre-White Clothesline of MELOSTRENGTH® Paper. This paper is treated with MELOSTRENGTH® Resin, which makes a water-insoluble bond between paper fibers. The paper is stronger, wet or dry, has high wet-rub resistance so it may be wiped clean easily. And it resists chafing of clothespins through wet laundry. This economical clothesline is one of many improved paper products made possible by MELOSTRENGTH Resin. **(Industrial Chemicals Division, Department A)**

(Left) **AND HER LINENS COME WHITER,** thanks to triazine-type brighteners based on AERO* Cyanuric Chloride. These optical bleaching agents absorb ultraviolet radiation and emit it as visible wave lengths in the blue portion of the spectrum. This fluorescence counteracts yellowish or greyish soil, and increases the total light reflectance of the fabric, making it brighter as well as whiter. Optical brighteners also lighten pastel shades and increase color contrast in printed goods. Many other triazine dyestuffs have been derived from cyanuric chloride, which can also be used to make plastics of exceptional clarity and heat resistance, fungicides and insecticides, vulcanization accelerators and surface active agents. **(Industrial Chemicals Division, Department A)**

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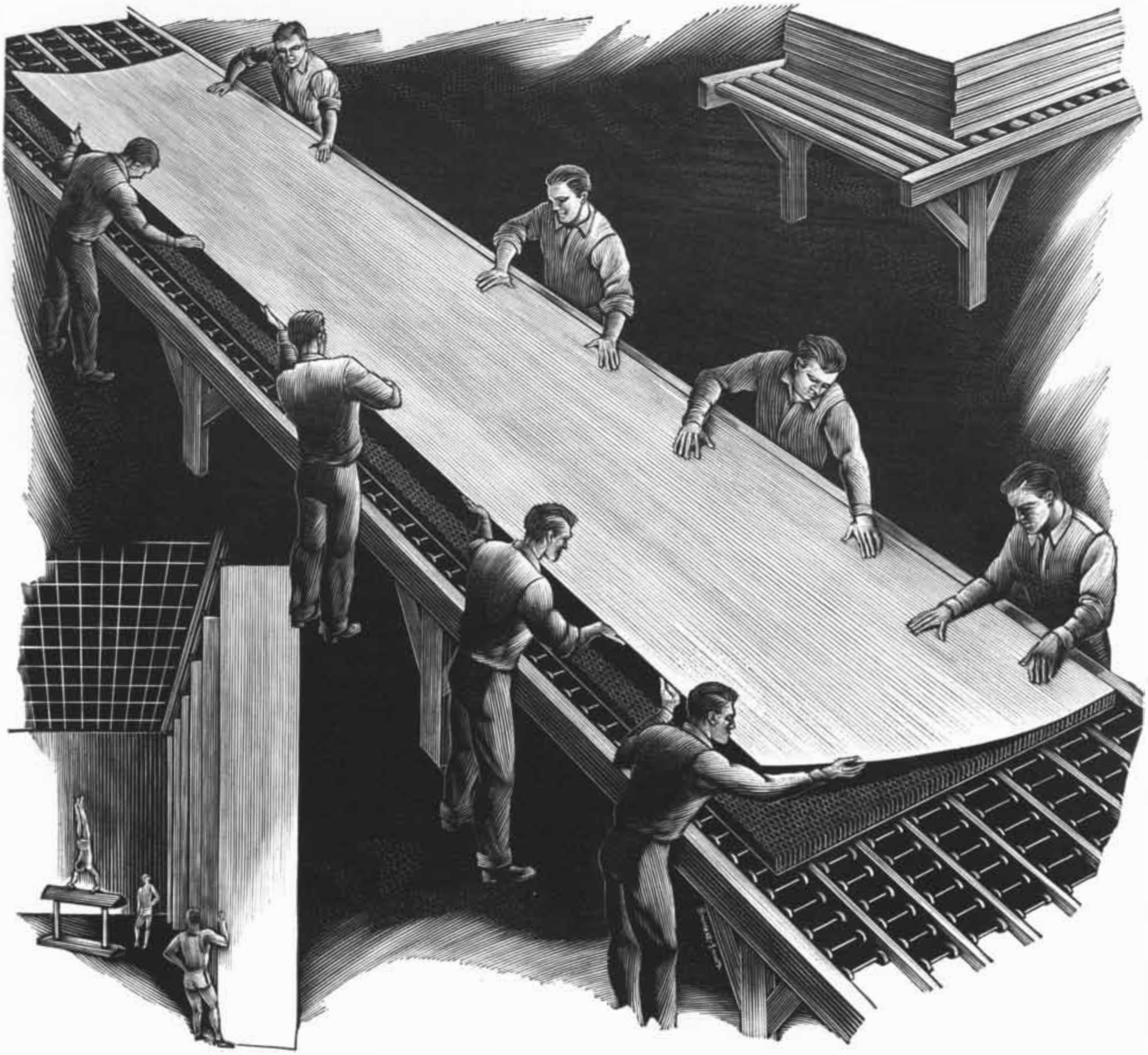
NEW AMINE HELPS WAX SHED WATER. Wax emulsions made with 3-methoxypropylamine, a volatile amine derived from acrylonitrile, give highly water-resistant films. Laboratory tests indicate that 3-methoxypropylamine will replace two to four times the amount of morpholine required in similar formulations. To prepare an almost transparent emulsion with fine gloss, Dura Commodities Corp., New York, N. Y., suggests this formula: 40 parts Duroxon J-324 mineral wax, 3 to 4 parts oleic acid, 3 parts 3-methoxypropylamine, and water. Emulsifying and dispersing action is equal to or better than that of morpholine, and similar results might be expected for other wax formulations. **(New Product Development Department, Section A)**

Building for the Future Through Chemistry

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



Bond 24-foot sandwich panels without jigs, clamps, or curing ovens

The assembly line in the picture is turning out 24-foot aluminum-honeycomb sandwich panels for use as gymnasium partitions. The adhesive being used is Armstrong D-253. With this remarkable adhesive, you can bond sandwich panels of any size that you can handle . . . without the need for costly jigs, clamps, or curing ovens.

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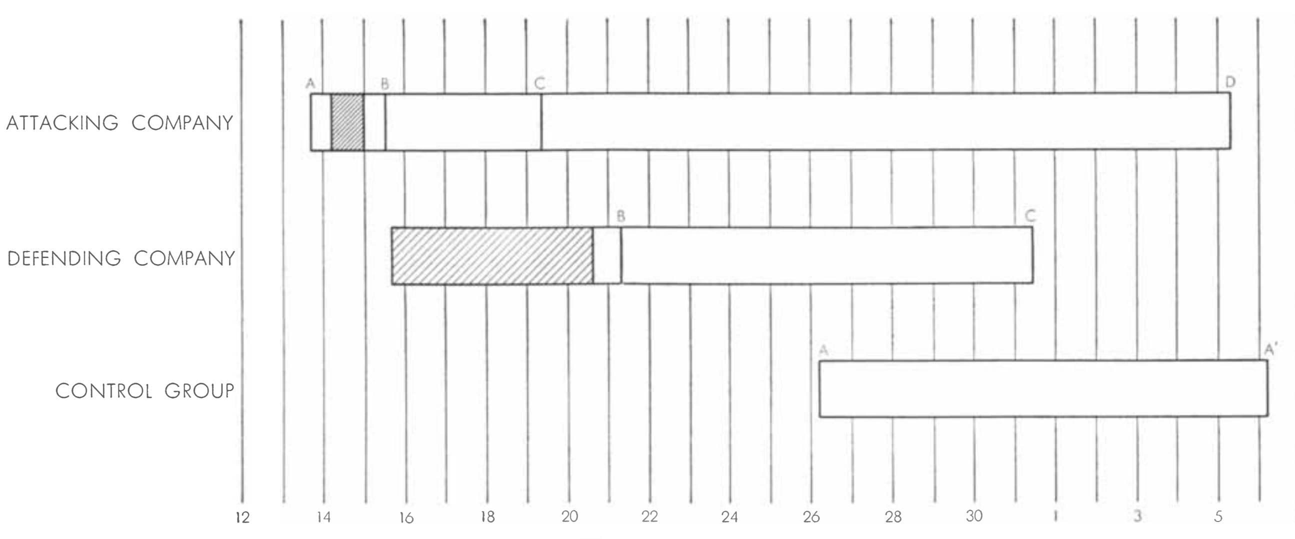
Stress in Combat

What physiological and psychological responses do men exhibit under great pressure? An account of a remarkable investigation undertaken by a group of scientists during an engagement in Korea

by Stanley W. Davis

The behavior of the human organism under stress is one of the major concerns of our time. We are living in a period when more and more is demanded of the human constitution, when man's capacities are being taxed ever more severely by his increasingly complex machines and the growing pressures under which he lives. No wonder, then, that reactions to stress have become a subject of systematic study in recent years. Inevitably the main focus of this investigation has been military, for it is in combat that human beings are exposed to the greatest stress and the problem of human limitations becomes most critical.

The machinery of modern warfare advances steadily in power and complexity. Planes fly faster, guns shoot farther and more rapidly, instruments grow more intricate, and the whole system of military tactics and strategy is being revolutionized by nuclear weapons. Yet the soldier, who must handle these weapons and on whom the fate of the battle ultimately depends, remains essentially unchanged from the days of the Roman legions. The importance of the human factor was grimly demonstrated on D-day of World War II. The U. S. invasion forces had been picked with extreme care, had been trained for months and were provided with the finest weapons. But when they hit the beaches of Normandy, many men were unable even to muster enough strength to carry a machine gun across the beach; later accounts told of squads and even



MEN IN THREE GROUPS were studied from October 13 to November 7 in 1952. The attacking company took two hills. The defending company held these positions against attack. The control group occupied positions about 200 yards behind the main line of battle. The shaded portions of the bars indicate time spent in combat. The darker shaded portion represents more intense combat; the lighter shaded portion, less intense combat. The letters A or A' indicate measurements made before combat. The letters B, C and D indicate the second, third or fourth measurements. These were made after the first two groups of men had retired from combat.

INFANTRYMEN in the regiment studied by the investigators move up in the Triangle Hill area on October 14. The smoke in the distance is from bombs dropped by fighter-bombers. On the same day the regiment occupied several hill positions in the area.

CASUALTIES of the same attack lie on stretchers at a battalion aid station. The attacking company studied by the investigators suffered 61 per cent casualties. Of the 24 men originally selected for the study, only five were uninjured and available for tests.

whole platoons that stood where they were, powerless to move, when they left their landing craft. Something had happened to these well-trained, well-equipped, well-led fighting men. The stress of combat had paralyzed them as effectually as enemy bullets could have.

It has become increasingly evident that military commanders must have a thorough understanding of the effects of combat stress to make the most efficient use of their manpower. With such knowledge they could judge whether a unit was adequately prepared for battle, how long it could fight effectively and how much rest it should be given before being sent into action again.

During the Korean war the U. S. military services made a study of combat stress as a first step in a long-range program to find answers to some of these problems. It was an on-the-spot examination of infantrymen in a combat area in Korea, carried out under an Army contract by a team of investigators—physiologists, psychologists and psychiatrists. The team was made up of personnel from the Johns Hopkins University Operations Research Office, the Office of Naval Research, the Naval Medical Research Institute and the Army Surgeon General's office.

The object of the study was to examine men after they had come out of combat to see whether the stress had produced measurable changes in physiological and psychological capacities, and to observe how long these changes persisted. Since this was a pioneer study, we had to decide first what specific tests were most likely to be significant for our purpose.

For the physiological tests we selected as the main target the adrenal gland, because it is well known that this small gland plays an important part in adjustments to stress. We used two kinds of measurement to estimate the level of this gland's activity. First, we estimated the amount of cortical hormone secreted by the gland. This was done by analyzing the urine for its content of the hormones themselves (principally the one known as Compound F) and of certain end products of the metabolism of the hormones (the so-called 17 ketosteroids). Secondly, we measured the effects of the adrenal hormones on other tissues and organs. The adrenal hormones affect the production of various types of white blood cells, the breakdown of proteins into products such as urea and uric acid and the balance of salts in the body; changes in these factors can be determined by analyzing the blood and the urine.

We also tested for changes in the percentage of red cells in the blood, for changes of blood volume, for sugar in the blood and urine and for cholesterol and carbon dioxide in the plasma. We also administered two stimulating drugs: Mecholyl to test the reactivity of the autonomic nervous system and ACTH to test the functioning of the adrenal cortex. In all we used more than 20 different physiological tests.

To examine how the soldiers' mental functioning had been affected by combat stress, we selected 14 psychological tests, designed to measure their judgment, speed and sensitivity of perception, memory span and so on. These tests, as it turned out, yielded disappointingly little information, so the main value of the Korean study was in the physiological results.

The laboratory where most of the testing was done was located at a mobile surgical hospital one jeep-hour away from the main battle line in Korea. Set up in a Quonset-type hut, it was equipped with excellent facilities for physiological and chemical studies, including radioactive tracer work, ion-exchange separations and so on. In addition we had mobile equipment which could be carried to the front line for examination of men there.

A combat theater, some said before we went to Korea, is a place to fight a war, not to do research. But the military services were convinced that the kind of information they needed could be obtained only in a combat zone, and we received fine cooperation and assistance from all concerned—commanders and men alike. Groups of soldiers whom we examined had to submit to four to six hours of testing just after they had been pulled out of intense combat. It involved sticking them with needles and required them to stay alert when what they wanted most to do was sleep. Yet these men were without a doubt the most cooperative group of subjects with whom any of the scientists had ever worked. The men knew that the examinations would be of no benefit to them; nevertheless they welcomed the chance to take part in the study, both as a relief from the boredom of military routine and as a contribution for the benefit of future generations of infantrymen. The *soldiers* thanked the *scientists* for letting them serve as subjects.

Three groups of men were examined; let us take each in turn.

The first was a control group of 24 infantrymen from a company occupying blocking positions about 200 yards behind the main line of battle. These men were under occasional artillery and mortar fire, were under constant threat of attack, were called upon to make fre-

URINE MEASURES	ATTACKING COMPANY	DEFENDING COMPANY
17 KETOSTEROIDS	HIGH	LOW
PORTER-SILBER CHROMOGENS	HIGH	LOW
UREA	HIGH	NORMAL
URIC ACID	HIGH	NORMAL
CREATININE	HIGH	NORMAL
SODIUM/POTASSIUM	LOW	HIGH
CHLORINE	LOW	LOW
BLOOD MEASURES		
LYMPHOCYTES	NORMAL	LOW
EOSINOPHILS	LOW	NORMAL
TOTAL WHITE COUNT	LOW	NORMAL

ATTACKING AND DEFENDING COMPANIES differed in their physiological responses. The measures tabulated here were made 12 hours after combat in the Triangle Hill area. The 17 ketosteroids and Porter-Silber chromogens are direct measures of adrenal-hormone output. The other measures are of by-products of processes affected by these hormones.

MOBILE SURGICAL HOSPITAL at which the tests were made was photographed from the air by Muriel Johnston, a member of the team. The hospital was about an hour's drive from the main line of battle. The laboratory is the Quonset hut at right center.

quent patrols; one subject was killed by a mine. However, their situation was considerably less dangerous than that on the fighting line, and their physiological condition proved to be normal. By the physiological measures applied they did not differ significantly from normal non-combatant males in the U. S. Thus this group served as a base line or standard for judging the changes produced by the stress of actual combat.

The second group consisted of men who went through the most intense kind of combat: an attack on a heavily defended hill. They were selected from the lead company of a battalion which stormed and took two peaks in the Triangle Hill area north of Kumhwa on October 14, 1952. The engagement lasted 18 hours, and the company suffered 61 per cent casualties. The 24 selected men were examined 12 hours before they went into action. After the attack only five of these men were uninjured and available for retesting. Fifteen other men from the remnants of the company were therefore added to the group. These 20 men were examined at three intervals after their return from the battle: 12 hours afterward, again after five days and again after 22 days.

At the first postcombat examination they were a very tired group of men, showing visible signs of their physical and emotional ordeal. Physiologically the most striking change was a marked rise in the output of hormones by the adrenal gland, as shown by our various indices. There was an increase in steroids (breakdown products of the hormones) and in protein metabolism (as measured by urea, etc.). The balance of salts had changed, showing a smaller ratio of sodium to potassium. The white blood-cell count had dropped. This last was a particularly interesting development. Most types of stress produce a rise in the white-cell count; in this case the number of young white cells had increased as usual but the total count was lower because adult white cells had practically disappeared. Severe infection or burns sometimes produce such a change, so the white-cell fall may be taken as a measure of the severity of the stress to which the combat soldiers had been exposed.

Five days after their combat experience most of the elements in their physiological picture had returned to normal, and 22 days afterward it was entirely normal. We estimated that on the average it took the men in the attacking company about six days to recover physiologically from their intense 18-hour stress in combat.

The third group went through a stress which was somewhat less intense but more prolonged. We called it "the defending company." It comprised 13 men from a company which took over the captured positions on Triangle Hill and defended them against counterattacks. These men were in the fighting line for five days, stood off three attacks and were bombarded continuously by artillery; they suffered 17 per cent casualties.

The 13 men in the defending company were examined 12 hours after they came out of combat and again eight days later. Their physiological profile was completely different from that of the attacking company. The immediate postcombat tests indicated that their adrenal activity was below normal instead of above normal. And it took these men an average of 13 days to regain physiological normality.

Opinions differ as to the reasons for this surprising contrast between the attacking and defending companies. It can be explained neatly, however, by Hans Selye's theory on the response of animal organisms to stress [see "The Alarm Reaction," by P. C. Constantinides and Niall Carey; SCIENTIFIC AMERICAN, March, 1949]. According to Selye's hypothesis, this response, which he calls "the general adaptation syndrome," progresses in three stages. In the first, the activity of the adrenal gland is speeded up. This appears to describe the condition of the attacking company after its relatively short (18-hour) but

Editor's Note

The team which made the study reported in this article included, in addition to the author, Commander Nello Pace, Lieutenant Frederick L. Schaffer, Lieutenant John H. Kilbuck, Lieutenant Elaine Walker and Lieutenant Muriel Johnston, representing the Office of Naval Research; Lieutenant Commander David Minard, representing the Naval Medical Research Institute; Lincoln F. Hanson, Fred Elmadjian, Howard S. Liddell and Algird Zilinski, representing the Johns Hopkins Operations Research Office; Captain Ernest R. Kolovos and Captain George H. Longley, representing the Office of the Surgeon General, Department of the Army. Also contributing to the study was Jean G. Taylor of the Operations Research Office. Miss Taylor did not accompany the team to Korea, but analyzed much of its data and co-authored its report to the Army.

A complete discussion of the physiological findings of the study will shortly be published by the University of California Press under the title *Physiological Studies of Infantrymen in Combat.*

intense period of combat. As the stress continues, the organism enters a second, "resistance" stage, during which adrenal activity drops, sometimes to below normal. After prolonged stress the organism finally reaches the "exhaustion" stage and no longer is able to maintain its resistance.

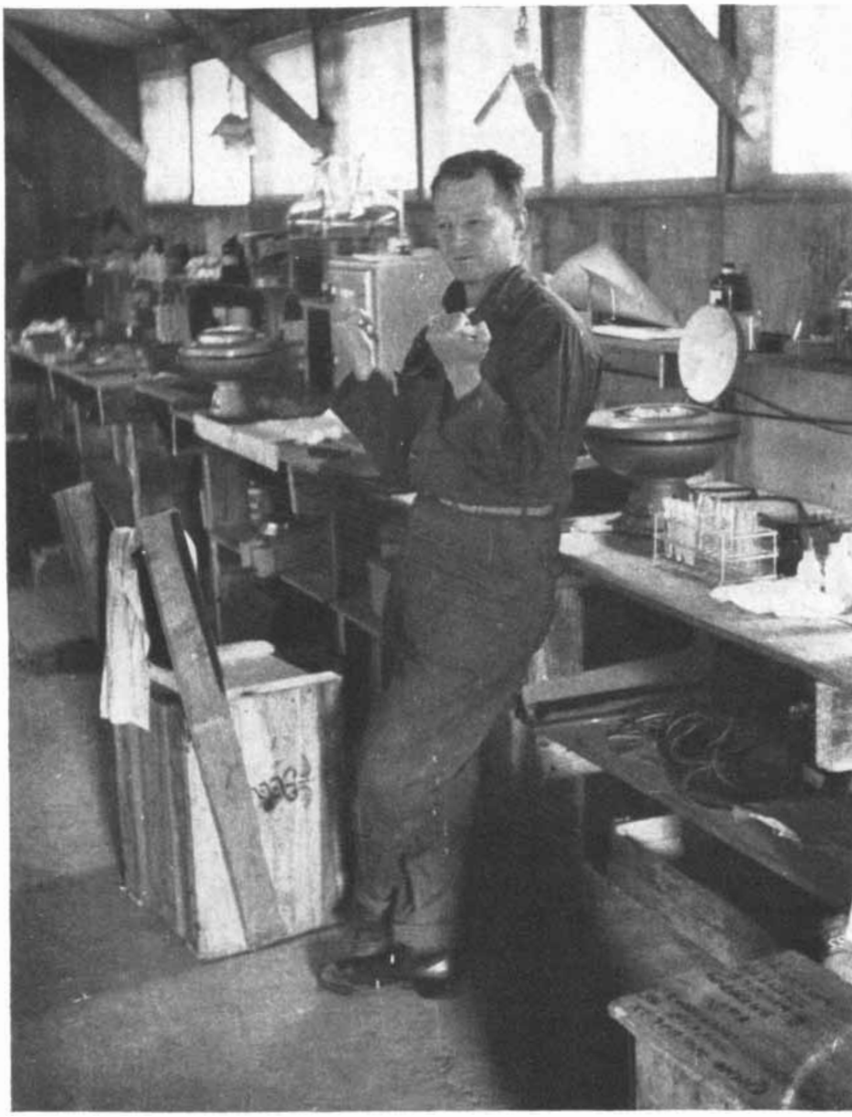
Whether the men in the defending company were in the resistance or exhaustion stage, from the standpoint of adrenal activity, is uncertain; tests of the ability of their adrenal glands to respond to the stimulating drug ACTH were inconclusive. It seems most likely that their adrenals were functioning at the resistance level.

One thing is certain: recovery from the acute stress of combat is a matter not of hours but of days. The time-honored rest cure for fighting troops—a hot meal and a good night's sleep—evidently is not sufficient.

As for psychological behavior, there could be no doubt that the stress of combat had changed the men profoundly. They were impassive, lethargic, uncommunicative, almost antisocial, where before being sent into combat they had been exuberant—telling stories, laughing and back-slapping. Yet our psychological tests failed to show any evidence of changes matching those in physiology. The men's mental faculties seemed to be unimpaired—with two comparatively minor exceptions. They were a little less sensitive in certain tests of perception: that is, in ability to detect flickering interruptions of a beam of light and analogous interruptions of sound. This decrease in sensitivity is known to be an indication of mental fatigue and to stem in part from changes in the central nervous system.

The lack of significant results from the psychological tests was disappointing but not greatly surprising, because it was impossible to control the test conditions adequately. Further research will have to be done to find appropriate ways and means of measuring the psychological changes produced by combat stress.

The Korean study was just a beginning in the direct investigation of the extreme stress of combat. It demonstrated that this stress produces important and substantial changes in bodily functions. The meaning of these changes has to be explored further, and other measures of the effects of stress need to be devised. A fuller understanding of these effects should be invaluable not only in the military field but also in everyday life.



LABORATORY WORK was done under field conditions. At the top Frederick Schaffer of the Office of Naval Research shakes test tubes. At the bottom medical technician Algird Zilinski boils urine samples with acid, part of the process for extracting 17 ketosteroids.

Forest Clearance in the Stone Age

During the Neolithic period the hunters of northern Europe gradually became farmers. Using their tools and methods, Danish investigators have re-enacted how they cleared the land and cultivated their crops

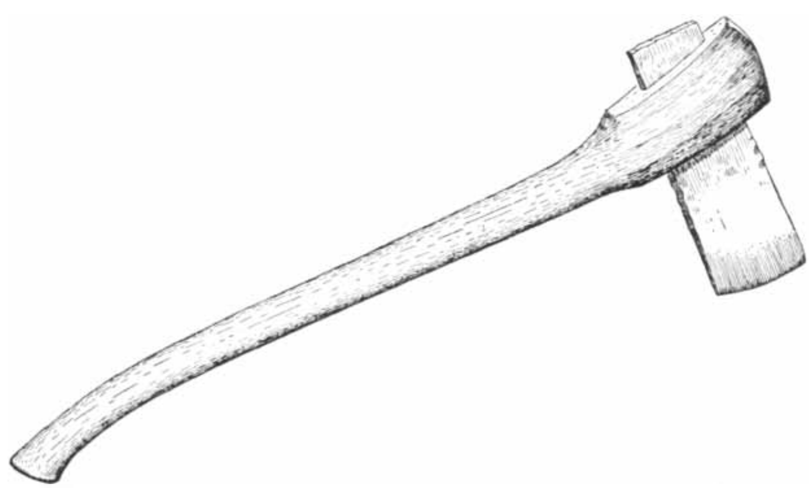
by Johannes Iversen

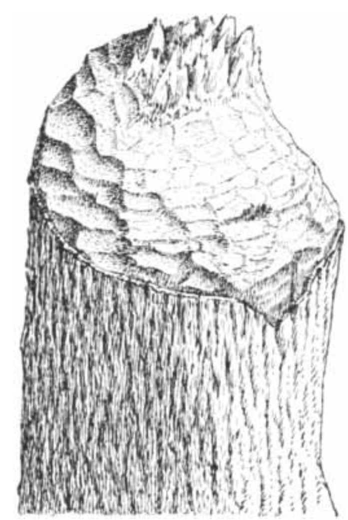
Perhaps the greatest single step forward in the history of mankind was the transition from hunting to agriculture. In the Mesolithic Age men lived by the spear, the bow and the fishing net; in the Neolithic Age they became farmers. The change came independently at different times in diverse parts of the world. Just how and when men turned to farming in Western Europe has been a subject of debate among naturalists and archaeologists for a hundred years. New methods of dating the implements of Stone Age men have recently given more factual substance to the debate. What is more, we have learned enough about the world in which they lived to test our theories about how they lived by experiment. This is a report of a set of experiments by which a group of scientists in Denmark attempted to re-enact some aspects of the hunting-to-agriculture chapter of mankind's past.

Denmark has unearthed relics of both stages—the bone and flint implements of the Mesolithic hunters and the polished stone axes of the Neolithic farmers. And in ancient lake sediments and bogs the prehistoric tools lie in recognizable strata of pollen, that marvelous dating instrument which identifies each period by its prevailing vegetation. The pollen record, as ecologists read it, tells the following story.

Toward the end of the last ice age, when vegetation was emerging and the country was still open, hunters ranged all over Denmark. Then, as forests grew dense and reduced large game, men abandoned the forested interior and retreated to the coast, where they made their living by fishing and seal-hunting. This state of affairs continued for thousands of years, until man suddenly appears in the forest, hacking out a new living. Clearings are hewed in the primeval forest. Tree pollen rapidly declines in certain regions, and we find in its place a sharp rise in pollen of herbaceous plants and the emergence of cereals and new weeds, notably plantain—the plant which the Indians of North America called "the footsteps of the white man."

Very shortly a new growth of tree species which typically follow forest clearance—willow, aspen, birch—springs up. The presence of birch strongly suggests that man used fire to help clear the forest, for on fertile soil birch succeeds





STONE AXE was reconstructed by mounting the Neolithic flint head on a copy of a Neolithic haft preserved at the bottom of a bog. It was found that the full swing of the modern woodsman often chipped or broke the head. Using short, rapid strokes, the experimenters learned to fell trees more than a foot in diameter in 30 minutes. To fell small trees they chopped all the way around the trunk.

a mixed oak forest only after burning. Meanwhile the ground flora undergoes a radical and significant change. Grasses, white clover, sheep sorrel, sheep's-bit and other pasture plants take the upper hand. We can visualize cattle grazing and browsing in grassy meadows bordered by scrub forests of birch and hazel.

Finally comes a third phase. The grasses, birch and eventually hazel decline, and a big-tree forest takes over once more. Oak now is more dominant than before; elm and linden never recover the strength they had in the primeval forest.

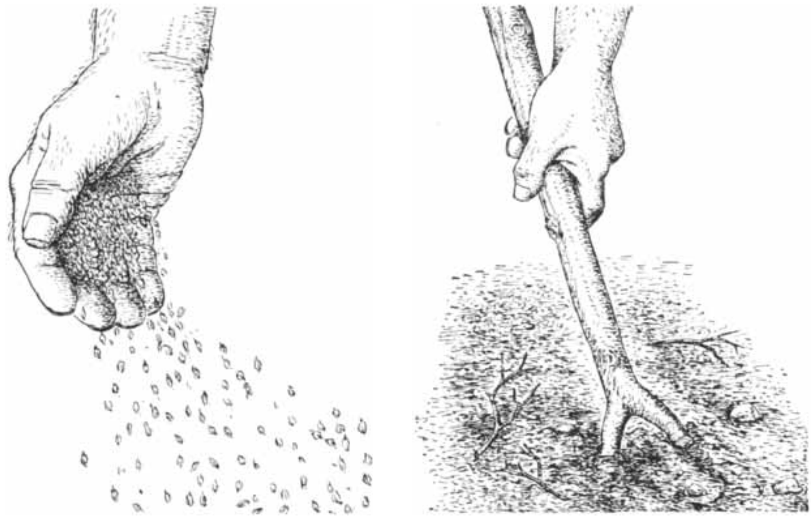
All this seems to mean that men cleared large areas of the original forest with axes, burned over the clearings, planted small fields of cereals and used the rest for pasturing animals. Their colonization was of short duration: when the forest grew back, they moved on to clear a suitable new area. According to the pollen record, some of their settlements can scarcely have lasted more than 50 years.

Now this is a neat, tidy theory, but there are troublesome questions. Could Neolithic man really have cleared large areas of the thick primeval forest with his crude flint axes? Could he have burned off the felled trees and shrubs in his clearings? Our team of ecologists and archaeologists decided to put these questions to the test of field experiment. We obtained the needed funds and permission to clear a two-acre area in the Draved Forest of Denmark, which is a mixed oak forest like that of Neolithic times.

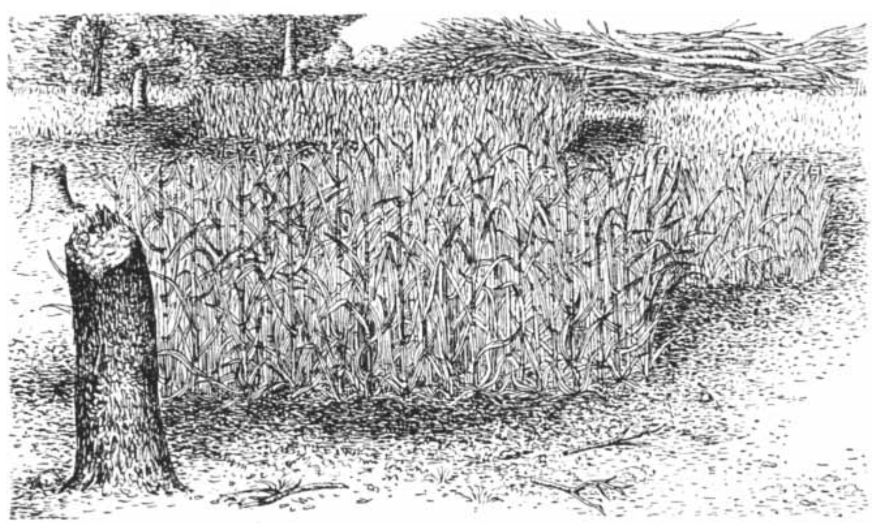
Two archaeologists, Jörgen Troels-Smith and Svend Jörgensen, took charge of the axe tests. They were able to obtain a number of Neolithic flint axe blades from the National Museum in Copenhagen, and a model for the wooden haft was available in the form of the famous Sigerslev hafted axe excavated from a Danish bog. In Neolithic axes, whose hafts were of ash wood, the blade was inserted in a rectangular hole in the haft [*see drawing on opposite page*]. Jörgensen and Troels-Smith demonstrated that if the haft was not to be split, it must not hold the blade too tightly but must leave room for a little sidewise play of the blade when it struck.

After making a number of hafted axes fitted with Stone Age man's blades, the two archaeologists, together with two professional lumberjacks, went forth into the forest in September, 1952. When the party attacked the trees, it soon became

TREES WERE BURNED by covering them with brushwood and igniting a 30-foot strip. When the strip was almost burned out, the larger logs were used to light the next one.



SEED WAS SOWN by hand in the still-warm ash (*left*). Then the seed bed was raked with a forked stick (*right*). The plants sown were barley and two primitive varieties of wheat.



BARLEY HAD GROWN to this height six weeks after it had been sown in the ash of the burned brushwood and trees. Barley sown in plots not covered with ash grew very poorly.

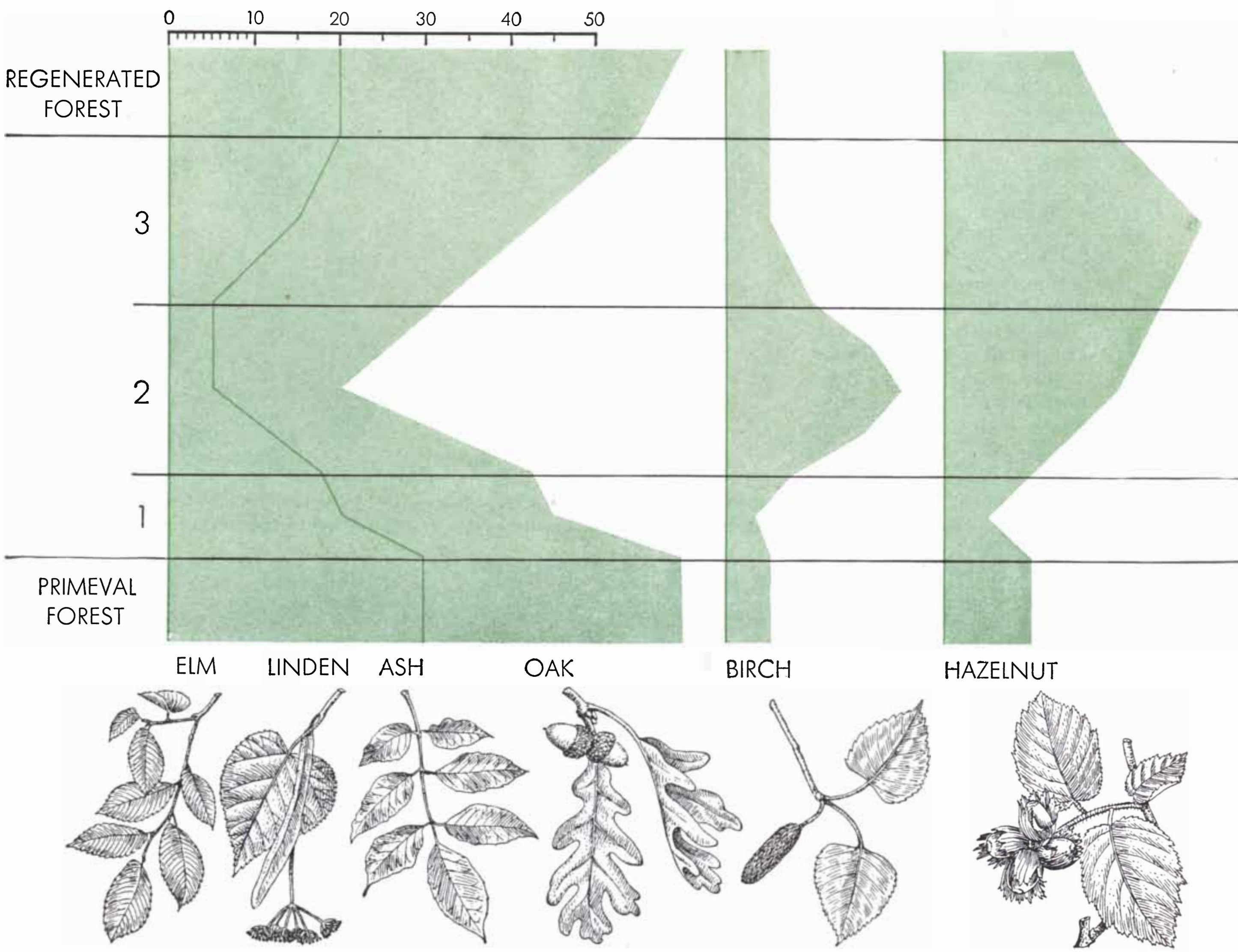
apparent that the usual tree-chopping technique, in which one puts his shoulders and weight into long, powerful blows, would not do. It often shattered the edge of the delicate flint blade or broke the blade in two. The lumberjacks, unable to change their habits, damaged several axes. The archaeologists soon discovered that the proper way to use the flint axe was to chip at the tree with short, quick strokes, using mainly the elbow and wrist. Troels-Smith, working with an axe blade which had not been sharpened since the Stone Age, employed it effectively throughout the whole clearing operation without damaging it.

When the two archaeologists reached peak form, they were able to fell oak trees more than a foot in diameter within half an hour. Small trees they dropped by cutting all around the trunk; on substantial-sized ones they used the slower method of hewing through notches on the opposite sides, in order to control the direction of fall. We realized that for clearing purposes it would be advantageous to have all the trunks lying in the north-south direction; for example, the wood would dry more quickly.

In this manner we cleared the two acres of forest, letting the largest trees stand but killing them by cutting rings through the sapwood. Troels-Smith and Jörgensen concluded that Neolithic men could have cut large clearings in the forests with their flint axes without great difficulty.

The next problem was to learn how they might have burned off their clearings. For help in this phase of the experiment we called on Kustaa Vilkuna of the University of Helsinki, who is an expert on primitive burning techniques which were still being used quite recently by farmers in the spruce forests of Finland.

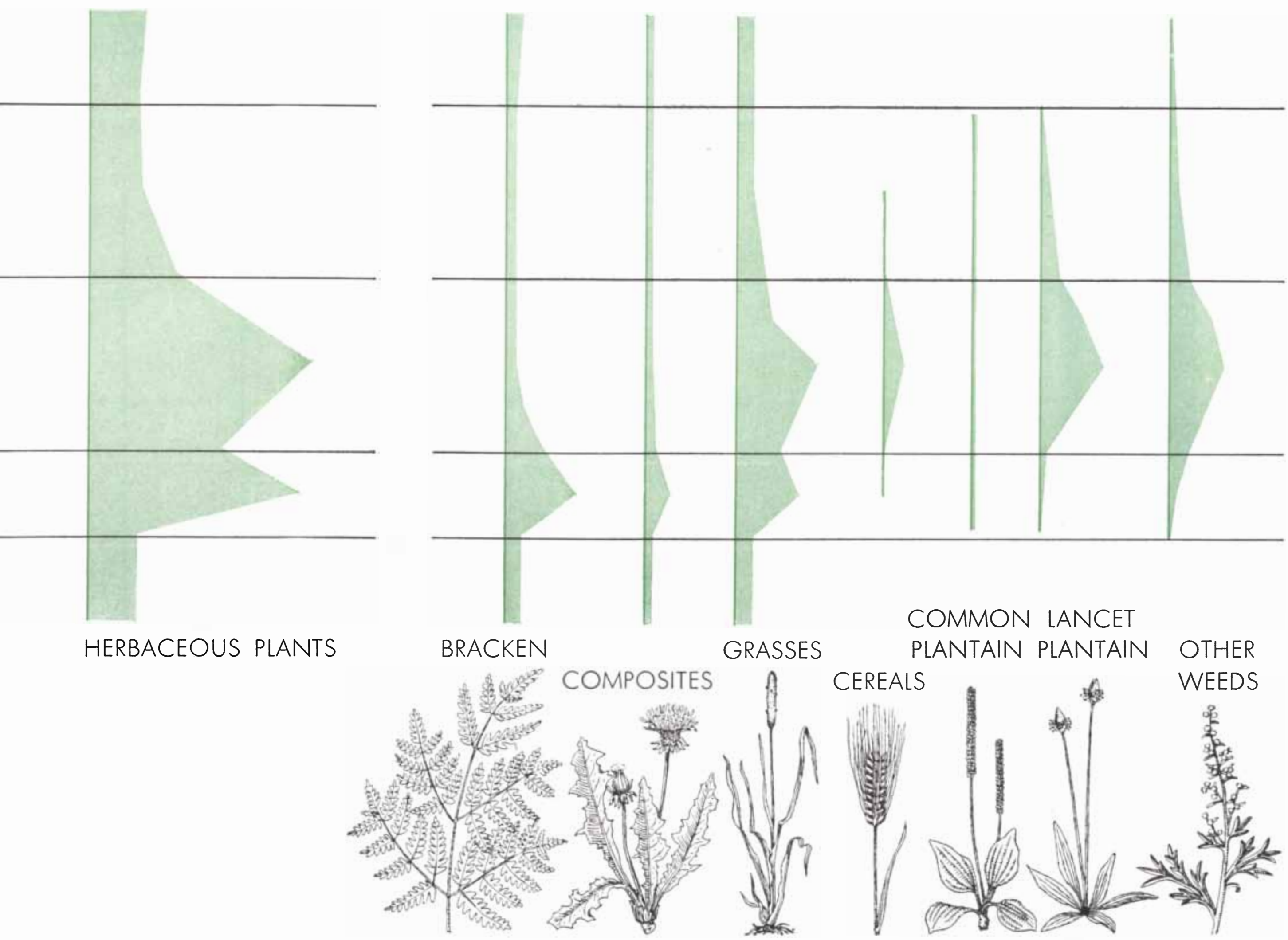
Without waiting for the wood to dry, we first tested two burning methods, one modern, the other primitive. The modern method, though effective in forests of conifers, failed completely in our deciduous forest. The primitive method, how-



POLLEN DIAGRAM shows the effect of forest clearance on the vegetation of Denmark between about 2500 B.C. and 2300 B.C. The diagram is based on many samples of pollen taken by boring down into bogs. The width of each colored area on the diagram represents the proportion of pollen from one species in comparison to that from all others. The scale of the proportions is given at the ever, was successful, and we proceeded to use it in the clearing in May of 1954, after the felled trees had had more than a year to dry. Brushwood and branches cut from the trees were spread over the area to be burned. Then this material was ignited along a 30-foot-wide belt by means of torches of burning birch bark attached to stakes. When the belt was well cleared, we pushed its still burning logs forward with long poles to set fire to the adjacent area. In this way we burned off the tangle of felled vegetation belt by belt. The fire was controlled carefully, day and night, to achieve an even and thorough burning of the ground. It was rather hard work, as oak wood burns slowly, but there were no serious difficulties, and in three or four days the job was finished. We burned only half of the two-acre clearing, because we wished to compare the subsequent growth on burned and unburned ground.

Immediately after the burning we sowed part of the area with primitive varieties of wheat (einkorn and emmer) and naked barley. That these cereals were grown in Denmark by Neolithic man is shown by grain impressions on excavated pottery. Axel Steensberg, an expert on agricultural methods, old and new, obtained seeds of the cereals from botanical collections and directed our agriculture.

We spread the seeds on the ground, raked them in with a forked branch, and waited for the harvest. For comparison we sowed two sets of plots—one burned and one unburned but hoed and weeded. The contrast in results was remarkable. On the unburned ground the grain scarcely grew at all. Evidently the rather acid forest soil was not suited to cereal growing. But the burned ground produced a luxuriant crop (which Steensberg harvested, in Neolithic fashion, with a flint knife and a flint sickle). The success of the cereals in this ground was due in part to sweetening of the soil by the wood-ash and the absence of competition from other vegetation, but the burning may also have created other beneficial factors, and we are now investigating this matter. In any case,



upper left. In the primeval forest (*colored areas below the bottom horizontal line*) the distribution of pollens was 30 per cent elm, linden and ash; 30 per cent oak; 5 per cent birch; 10 per cent hazel, and so on. During the three stages of forest clearance (*1, 2 and 3*) the distribution of pollens changed. The distribution of herb pollens is shown at the right of the break in the horizontal lines.

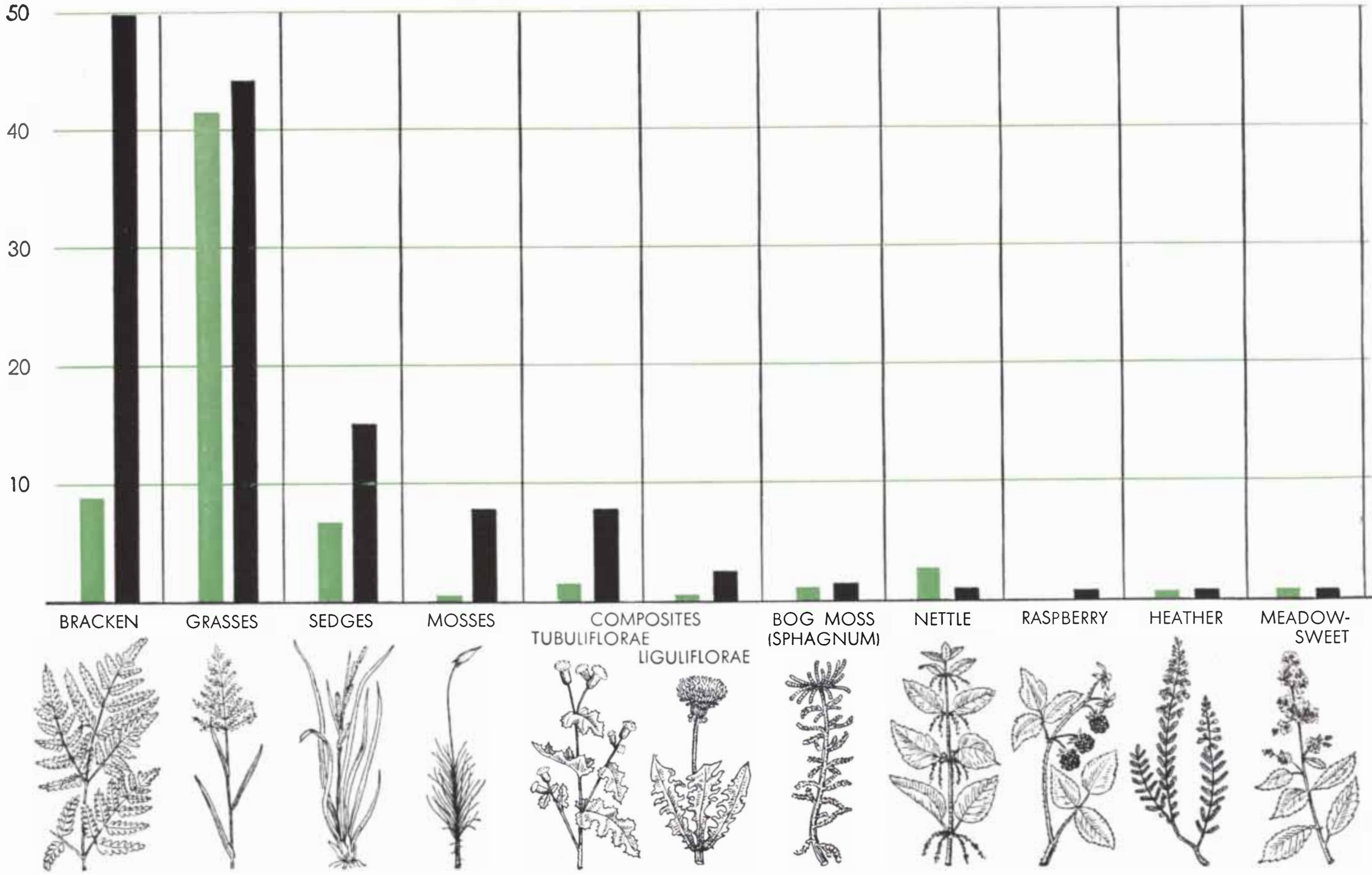
NEW COMMUNITY OF WILD PLANTS grew up in the parts of the clearing that had been burned over. At the left is a species of fern called bracken. Second from the left is hazel. Both of these plants had been present in the original forest. They grew up again

whatever the factors are, they are short-lived, for the second year the burned plots yielded much smaller crops.

Now, two years after the clearing and burning, we are in the process of watching developments in the early recovery of natural plant growth. The burned and unburned areas are developing quite differently.

In the area cleared of trees but unburned, events are following an unsurprising and unexciting course. The ground vegetation consists mainly of the species that grew there before the clearing, though it is growing more luxuriously because it has more sunlight. Bracken (ferns), always abundant in this part of the world, is flourishing far more richly than when it was shaded. Grasses and sedges have increased.

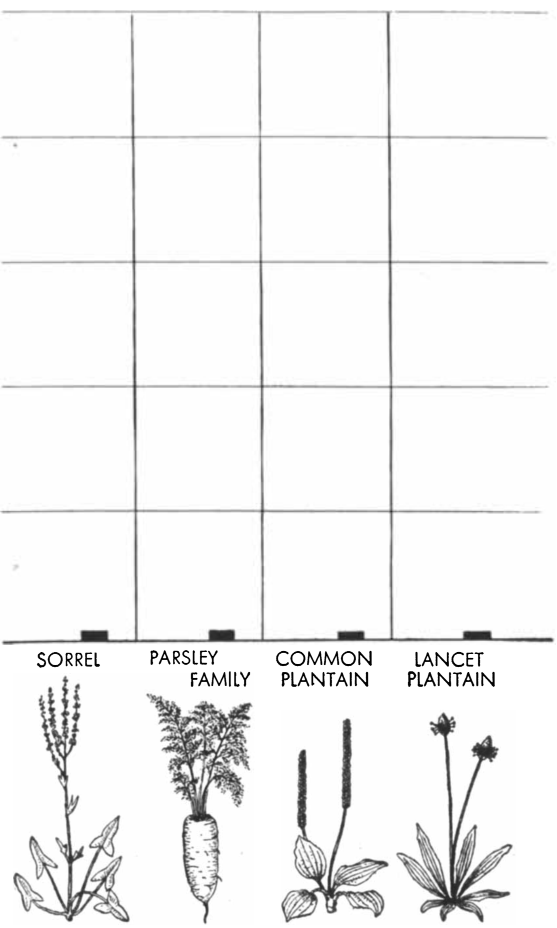
The burned ground, on the other



NEOLITHIC COMMUNITY OF WILD PLANTS that followed clearance and cultivation is analyzed in this pollen diagram. The colored bars indicate the amount of pollen from each plant before clearance. The black bars indicate the amount of pollen after clear-

from relatively deep roots. Third from the left are dandelions, members of a family which grows in profusion under such conditions. Fourth are mosses, which had never been seen in this forest before. Their spores were blown into the clearing on the wind.

hand, is a scene of botanical revolution. Bracken is coming back here too, but most of the other old plants, having shallower roots, were killed off by the fire. In their stead we have a whole garden of new plants. Plantain has made its appearance, just as it does in the ancient pollen record after forest clearance. There is a profusion of members of the family *Compositae*, including dandelions, daisies, sow thistle and so forth. (These plants do not bulk large in the fossil pollen record, but that is understandable because they are pollinated by insects rather than by the wind.)



ance. The scale at the left is based on grains of pollen per 1,000 grains of tree pollen.

A particularly interesting development is the sudden appearance of mosses and their spread over large patches of the burned area. The main species have never been seen in this forest before. Their spores have flown into the clearing on the wind, and no doubt mosses came the same way to the areas burned by Neolithic man. What makes them especially significant is that certain mosses seem to be definite indicators of fire; three species have been so identified in America, and sure enough the same three appeared in our burned clearing. Since the moss phase in a burned forest must be ephemeral, moss spores in the fossil record should enable us to pinpoint the dates of forest clearance by Neolithic man and to learn whether they burned the same clearing more than once during the existence of a continuous settlement. Unfortunately the small moss spores are difficult to recognize, and analysts of the ancient pollen deposits have not counted them hitherto. We made a small test count at the site of a Neolithic forest clearing in Denmark, analyzing the layers representing the time of the clearance and the period just before. According to our fragmentary count, there was a sharp rise in general moss growth (we made no attempt to distinguish individual species) immediately after the clearance of the area [*see chart at the left*].

Our experimental clearing in the Danish forest is just beginning to pass into the second phase, when pioneer trees appear and the regeneration of the forest commences. Birch seedlings are starting to spring up in profusion; willow seedlings have appeared; and hazel, aspen and linden shoots are rising from roots that were not killed by the fire. We are looking forward to studying this gradual regeneration in the years to come, as well as to reliving the stage in Neolithic farming when men grazed their cattle on the re-emerging ground vegetation.

Meanwhile we can say that so far our experiment has confirmed the archaeological interpretation of the pollen record on several important counts. It has been demonstrated that the forest could indeed have been cleared by the primitive tools of Neolithic man, and that in the first stage at least the reviving vegetation follows a course very like that deduced from the ancient pollen layers.

Of course man's transition from hunting to farming may well have taken other paths besides the one we have traced in the Danish clearings. More than one type of agriculture may have existed simultaneously in Denmark. As a matter of fact, Troels-Smith has found evidences of a more primitive agriculture during the same period on the Danish coast, where the Middle Stone Age men apparently cleared no forests but practiced a little crude farming along with their hunting and fishing.

The Neolithic farming culture described in this article is so much more advanced, and begins so suddenly, that it seems to signal the arrival and invasion of a vigorous new people from another region.

EXPERIMENTS IN PROTEIN SYNTHESIS

How does the cell assemble the small molecules of amino acids into the large ones of proteins? Here the problem is attacked by chemical dissection of the synthetic machinery of bacteria

by Ernest F. Gale

As readers of SCIENTIFIC AMERICAN well know, the past two years have been exciting ones in protein chemistry. The search for the secret of how living organisms make proteins—the basic material of life—has been rewarded by several important breakthroughs. Frederick Sanger and his group at the University of Cambridge worked out the complete structure of a protein molecule [see "The Insulin Molecule," by E. O. P. Thompson; SCIENTIFIC AMERICAN, May, 1955]. New clues and speculations have linked protein synthesis more definitely than before to nucleic acids, the heredity-carrying material in the cell [see "The Structure of the Hereditary Material," by F. H. C. Crick, October, 1954; and "Information Transfer in the Living Cell," by George Gamow, October, 1955].

Another new development of the past two years is that for the first time proteins have been synthesized by something less than a whole living cell. In the writer's laboratory at Cambridge preparations consisting of broken cells, containing only part of the normal cell material, have proved capable of making proteins when supplied with the necessary components. This has made possible some detailed studies of the role of the nucleic acids in the process of synthesis.

Before we consider these experiments, let us review the general outlines of the present view as to how proteins are formed. Proteins are long chain molecules built up from 20 different amino acids as units. The properties of each specific protein are determined by the proportions and most especially the order of arrangement of amino acids in the chain. The great question at the moment is: What mechanism arranges the units in the proper sequence to make a given protein? Here the nucleic acids (known as DNA and RNA) come to the fore. They are known to be long chain molecules. Various kinds of evidence suggest that DNA may act as a template, or pattern, which lines up amino acids in a specific sequence because attachment sites along the chain have specific affinities for particular amino acids. Once a full sequence of amino acids has been lined up in this manner, an enzyme may then bond the units together and peel off the newly formed chain, leaving the DNA available to organize another. As for the function of RNA, there has been less information to go on, but it has seemed likely that this nucleic acid plays a more elementary role, being involved somehow in promoting the cell's synthesis of proteins in general.

In our laboratory we have pursued the question of DNA's and RNA's activities by examining parts or stages of the process of protein synthesis. We have worked with broken cells and followed chemical transformations with radioactive tracers.

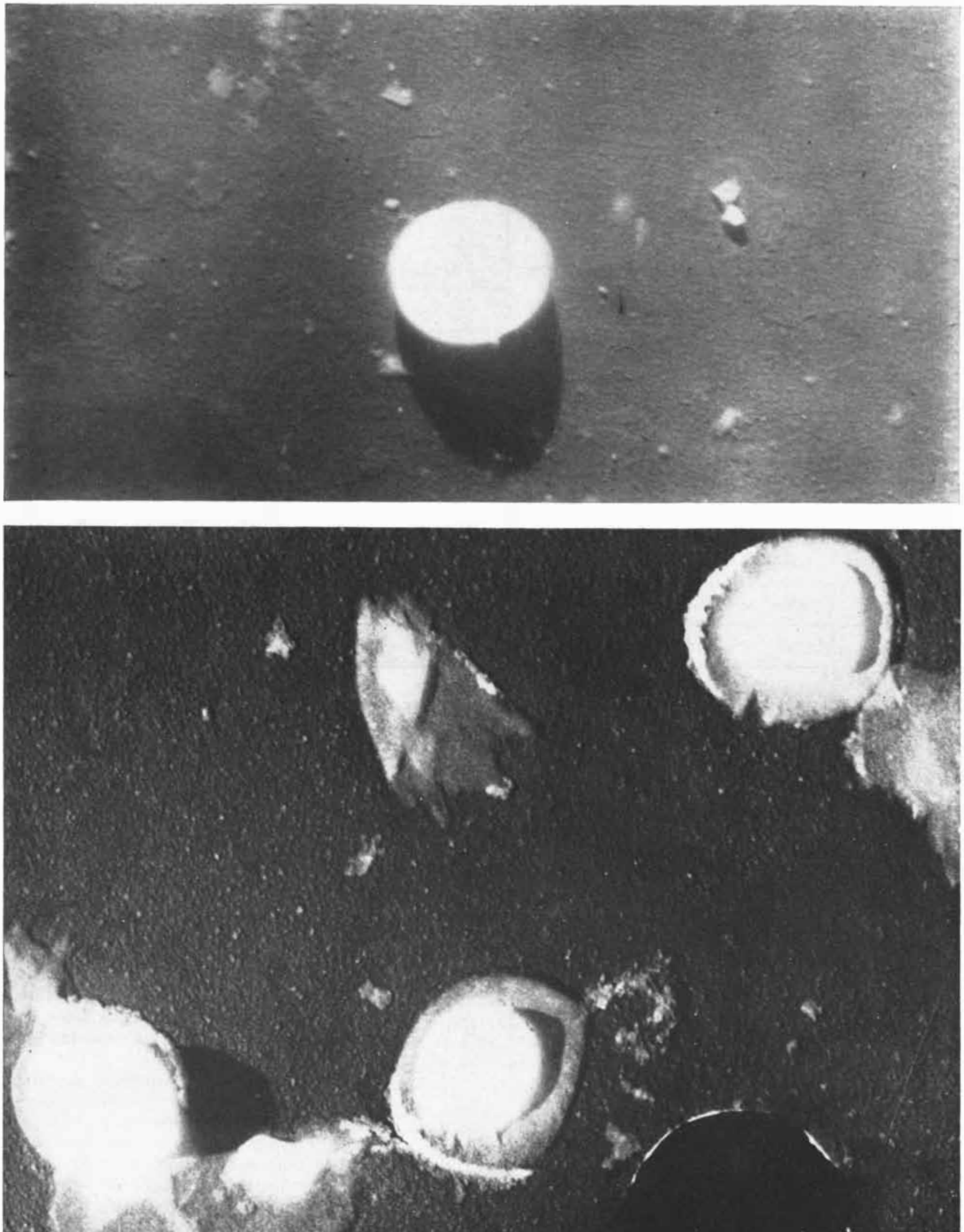
Our experimental cell is *Staphylococcus*, a bacterium well known as the cause of boils and other pus-forming conditions. One of the things that make this organism particularly suited for our work is that it can synthesize an amount of protein equal to its own weight in about 90 minutes.

After washing a culture of the bacteria on a centrifuge and concentrating them in a thick suspension, we cool them in an ice bath and shake them at supersonic vibration speed for 30 to 40 minutes. This treatment ruptures most of the cells, but some of these are broken only to the extent of having a tear in the cell wall [*see photograph at the bottom of the opposite page*]. Large molecules can pass through the gap, and thus we can add or remove nucleic acids or proteins within the cell.

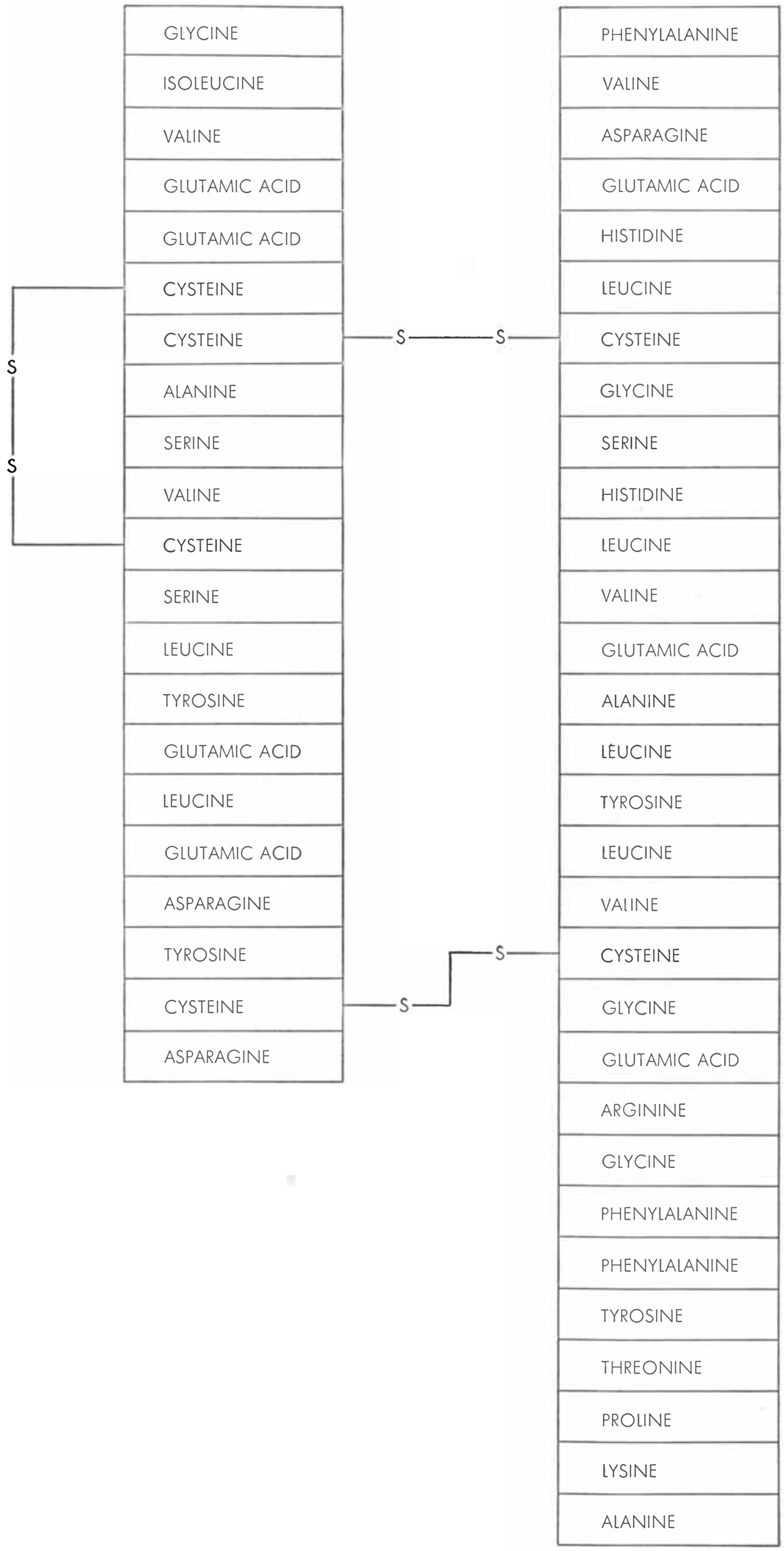
To establish whether these cells are capable of synthesizing proteins under given conditions, we need an accurate means of estimating their protein content. A convenient method is to measure their enzyme activity. Enzymes are proteins, and therefore an increase in the cell's enzymic activity means that it is synthesizing these proteins. Particularly useful for this sort of measurement are the so-called adaptive or inducible enzymes. They are a type of enzyme which a cell produces only when the specific substrate upon which the enzyme acts (or a chemically similar "inducer") is present. One such enzyme, for example, is beta-galactosidase, which breaks down beta-galactosides—compounds containing the sugar galactose. Staphylococcus bacteria grown in a medium devoid of galactosides will not make or contain this enzyme. If we then add some galactose to the cell preparation as an inducer, the cells will begin synthesizing the enzyme and we can measure its production from scratch.

There are, of course, other ways of estimating the rate of protein synthesis by a cell, such as study of the production of other types of enzymes or chemical analysis of the cell's products. We have used all these methods.

What, then, are the capacities of our collections of incomplete cells? Let us submit them to a series of tests. If the cells contain half their normal amount of nucleic acid, we find that they are able to synthesize protein provided we supply them with the necessary building blocks (the 20 amino acids) and a source of energy (such as the compound



EXPERIMENTAL ORGANISM of the author and his colleagues is the common bacterium *Staphylococcus aureus.* The electron micrograph at the top shows an intact bacterium; it is about one micron (.001 millimeter) in diameter. The electron micrograph at the bottom shows several bacteria that have been broken open by subjecting their culture to ultrasonic vibrations. The dense material inside the cells appears to be largely a combination of nucleic acid and protein, which can now be removed by enzymes or by other treatment. Nucleic acid can then be added to the cells again, and its effect on the synthesis of protein observed in a controlled manner.



INSULIN MOLECULE, like the molecule of any protein, is made up of amino acid units (*labeled rectangles in this schematic diagram*). The units are arranged in two chains, one of 21 amino acids (*left*) and the other of 30 (*right*). The chains are joined by sulfur atoms (S).

adenosine triphosphate, or ATP). They will also make the enzyme beta-galactosidase if galactose is added.

Next we remove some of the nucleic acid (extracting or destroying it by chemical means). When the amount in the cell has been reduced to about 15 per cent of normal, the cell no longer can make protein. We can restore its ability to produce certain proteins, however, by adding back one of the extracted nucleic acids—RNA (ribonucleic acid)—or substances from which the cell can make RNA.

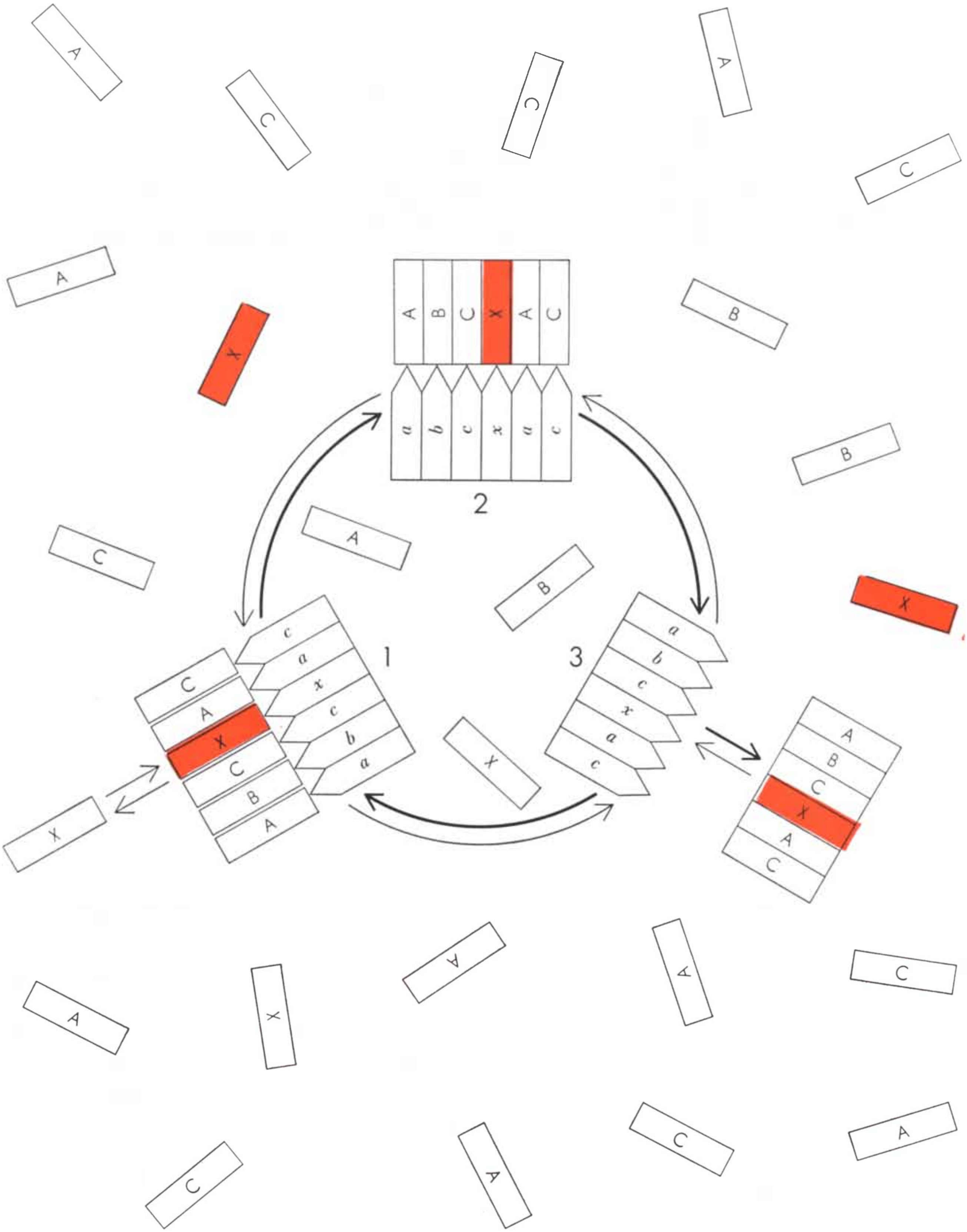
Finally, if we deplete the broken cells to less than 10 per cent of the nucleic acids they had originally, their ability to synthesize protein can still be restored if we add back both RNA and DNA (desoxyribonucleic acid). The nucleic acids must be of the specific kind peculiar to the strain of staphylococcus being studied. And the ability of the cells to make protein disappears if we inject enzymes that destroy the nucleic acids.

These experiments, then, proved clearly that DNA and RNA are involved in the process of protein synthesis by the cell. The next stage in the investigation was to study what roles they play.

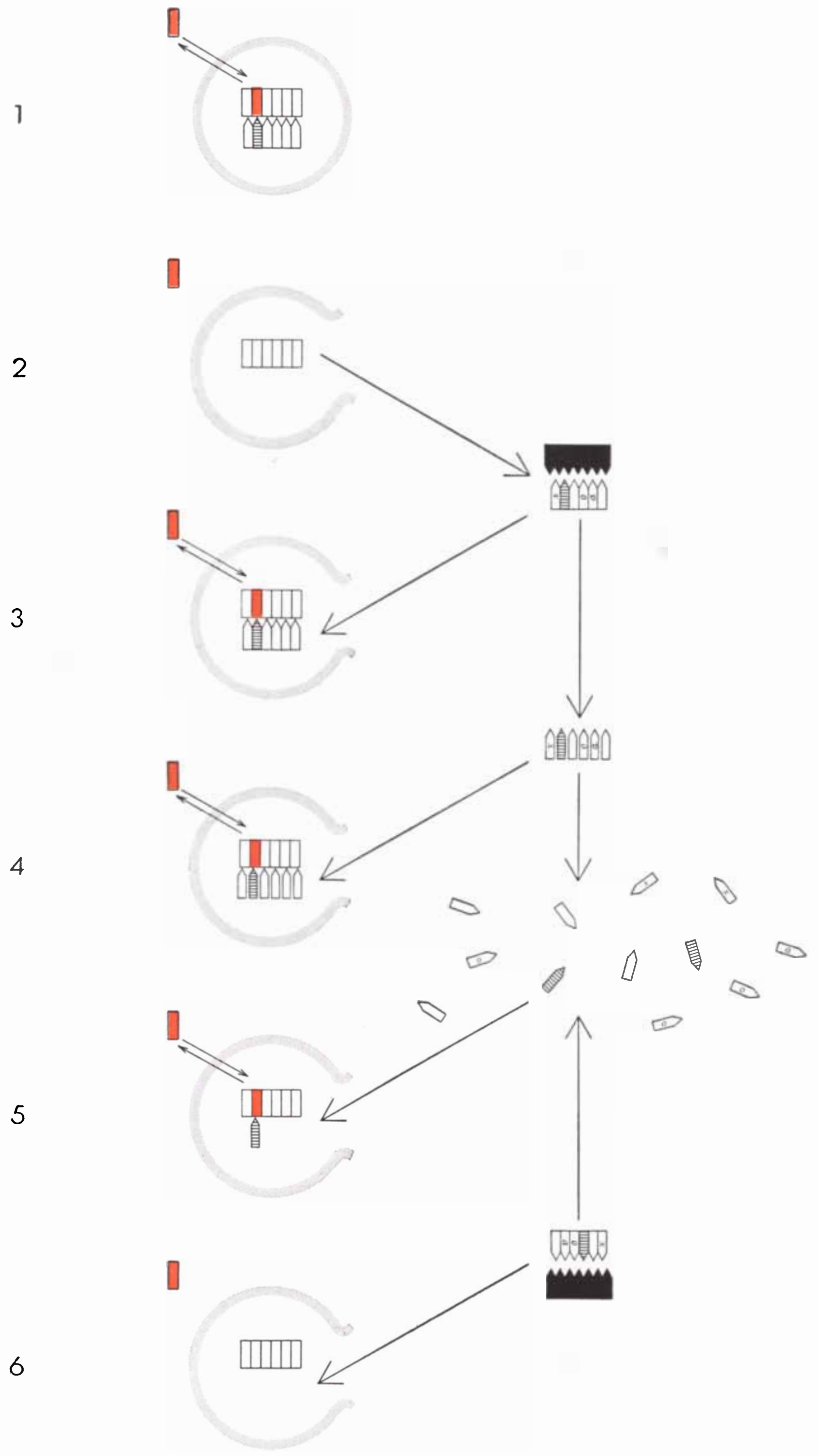
An interesting clue emerged from certain experiments with radioactive tracers. It has to do with the behavior of cells in which protein synthesis has been halted (*e.g.*, by the absence of some essential amino acid). If an amino acid labeled with radioactive carbon 14 is inserted in such a culture, the labeled amino acid often becomes incorporated in protein molecules, despite the fact that the cell is not making new protein! Somehow, without any rebuilding process that would involve the whole protein molecule, the labeled amino acid has displaced or usurped the place of a like unit in the molecule. Now the important fact that emerged from experiments with broken-walled cells was that this exchange takes place only when nucleic acid is present, DNA being about twice as effective in promoting it as RNA.

The template hypothesis suggests an explanation. In a mixture of different amino acids (the building blocks) and nucleic acid (the template) each site on the template attracts an amino acid with which it has a specific affinity [*see diagram on the opposite page*]. When all the sites become occupied, an enzyme bonds the amino acids together and peels them off the template as a unit.

If the medium lacks one or more of the necessary amino acids, so that the chain forming on the template cannot



TEMPLATE HYPOTHESIS of protein synthesis is illustrated in this much-simplified diagram. The objects resembling a short picket fence represent a single nucleic acid. The small rectangles represent various amino acids. Each picket of the nucleic acid has an affinity for one amino acid. Thus amino acids tend to line up along the nucleic acid in a specific pattern (1). The amino acids are then joined (2), and released as a protein (3). The double arrows indicate that the reactions are reversible. Where one arrow is heavier than the other, the reaction is more likely to run in that direction. If one amino acid is labeled with a radioactive carbon atom (*colored rectangles*), but some unlabeled molecules of the same amino acid are present, the two may change places (1).



UPTAKE OF AMINO ACID by *Staphylococcus* was shown to be controlled by nucleic acid in the experiments depicted here. At the top is a schematic representation of the bacterium (1). Its synthetic apparatus is intact, and labeled amino acid (*colored rectangle*) is incorporated into protein (*arrows*). If the cells are broken and their nucleic acid removed, the uptake of amino acid stops (2). If the nucleic acid is put back into the medium, the uptake of amino acid begins again (3). If the nucleic acid is broken down by the enzyme ribonuclease (*black*), and its fragments are added to the medium, the uptake of amino acid also begins again (4). There is some evidence that if a single fraction of nucleic acid is put into the medium it will cause the uptake of a single amino acid (5). This is supported by experiments with nucleic acid from yeast (*lower right*). If this nucleic acid is added intact to the medium, no amino acid is taken up (6). If the yeast nucleic acid is broken down, however, a single fraction of it will have the same effect as the similar fraction from *Staphylococci*.

be completed, the amino acids on the unfilled template remain unbound to their neighbors. Any of them may therefore be displaced by an identical amino acid free in the medium. In this way a labeled amino acid introduced into the medium might take a place on the template. Thus it would be in its appropriate position in the protein sequence. Eventually it might become incorporated into a protein molecule as a result of some kind of interchange between the protein and the amino acids arrayed on the template.

If this picture represents anything like the true situation, we should be able to learn a good deal about the mechanism of protein synthesis by giving more detailed study to the reactions whereby amino acids are incorporated through the aid of nucleic acid. We first investigated whether the whole nucleic acid, rather than some active fragment, was needed for this function. A nucleic acid can be broken by enzymes into fragments consisting of one, two, three or more of its component nucleotide units. When these fragments were tested, it developed that breakdown of DNA reduced its activity in promoting amino acid incorporation. In the case of RNA, however, fragments were as effective and sometimes even more effective than the whole molecule. Furthermore, RNA fragments were active in the staphylococcal cells even when the RNA came from some other source, such as yeast. This is especially surprising because yeast RNA when intact does not show such activity in the preparations of disrupted cells.

There are two possible explanations: either (1) the cell rebuilds its own type of RNA from the fragments, or (2) the activity lies in some RNA fragment or fragments which are active in the complete molecule only when in specific positions in its structure. Experimenting further, we have been able to rule out the first of these possibilities and are now separating the active substances in RNA. It may take many months to identify these substances.

Undoubtedly the process by which cells synthesize protein is highly complex and will be difficult to unravel. But it is now being investigated in detail by means of these and other broken-cell preparations in various laboratories around the world, and the next few years should prove exhilarating—and possibly exasperating—for all those working in this field.

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To a certain national wildflower society, however, which does have a beautiful color transparency of *Castilleja linearifolia* to reproduce in its bulletin, this order of expenditure is enough to chew its whole publication budget into shreds. Such figures have scared off many other societies and publishers of periodicals and books aimed at smallish audiences.

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The speed is the thing. You could revise the phone book every night. This is more important to civilization than you might offhand think. Civilization and commerce lean heavily on various books of listings, most of which are out of date before they ever go on the press, simply because the casting of hot metal into the shape of letters takes time and costs money. Some day, because of this machine, it may even be fair to declare it a misdemeanor to possess a badly out-of-date compendium without an archivist's license.

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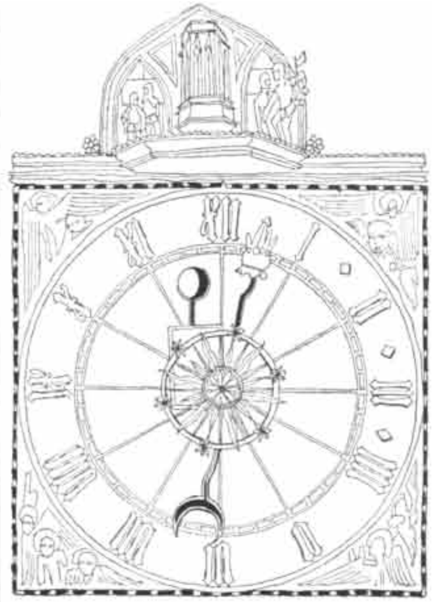

The Future of Atomic Energy

In 25 years the U. S. may be getting more electricity from nuclear power plants than it is generating in total today. In other fields of application atomic energy will probably contribute most heavily to agriculture and medicine. These are among the major developments foreseen by a citizens' panel which has been studying the impact of the peaceful uses of atomic energy. The group was appointed early in 1955 by the Joint Congressional Committee on Atomic Energy.

The panel's report, delivered last month, surveys the current state of the nonmilitary atomic art and recommends ways to promote its growth. The panel believes that this growth will be achieved without serious economic or social dislocations.

Reviewing the current power-reactor program, the report estimates that the way to economically competitive atomic power may become clear by 1960. In that case actual competitive plants could be in operation as early as 1965. By 1980, atomic power plants in the U. S. should be producing between 50 and 130 million kilowatts of electricity. At that time the total capacity of the country will have risen from its present total of a little more than 100 million kilowatts to between 400 and 600 million kilowatts.

A deficiency in the present program is its neglect of small and medium-sized reactors. All types should be developed as quickly as possible, says the panel, preferably with the help of private industry, but if necessary by the Government. If industry does not take on the job, the Atomic Energy Commission should build, at public expense, a full-scale "demonstration" reactor of every major type and size.

Difficulty in obtaining information is still holding up atomic progress, the panel finds. It recommends that the AEC remove "all reactor technology from the restricted data category, including . . . fuel element fabrication and processing techniques." The concept that atomic information is "born" classified should be abandoned.

Secrecy surrounding the thermonuclear program should be lifted as much as possible to allow more people to contribute. Furthermore, potential investors in fission power deserve to know something about fusion possibilities. Some light on the thermonuclear project was afforded by the report itself, in the background material published with it. Lewis L. Strauss, chairman of the AEC, explained in a letter why the project has been classified secret. "It appears," he said, "that any thermonuclear reactor will be a substantial producer" of neutrons which could be used to make plutonium or other "special nuclear material." This makes it "restricted data" under the Atomic Energy Act.

Agricultural research is assigned a high priority in the report. Plant breeders, using radiation to speed up mutations, have already developed superior strains of barley, oats, wheat, corn and peanuts. Soon they will have a variety of new types adapted to specific climate and soil conditions. Radioactive tracers are showing the way to more effective use of fertilizers.

Medical applications of atomic energy must be made more generally available, says the report. All medical schools should have facilities for teaching atomic techniques in research, diagnosis and treatment. Low-cost atomic medical equipment should be designed and provided for all hospitals. Radioactively labeled organic compounds, now expensive, should be widely distributed at reasonable prices.

The panel called for a big increase in atomic aid to foreign countries. Research specifically aimed at the problems of other nations should be undertaken. The report urges the U. S. to provide them with fuel and technical help for building reactors. It expresses the hope that by

THE CITIZEN

1960 enough reactors will have been built to produce at least one million kilowatts of electric power. This international program should be planned immediately in a series of regional conferences with cooperating countries.

Some of the other recommendations:

That atomic-powered merchant ships be developed.

That more research be devoted to the use of atomic radiation for processing materials.

That the AEC set up a separate division to handle peaceful applications of atomic energy.

The chairman of the study group was Robert McKinney, a New Mexico newspaper publisher. Other members were Ernest R. Breech, chairman of the board of the Ford Motor Company; George R. Brown, president of Brown Engineering Corporation; Sutherland C. Dows, president of the Iowa Electric Light and Power Company; John R. Dunning, dean of engineering at Columbia University; Frank M. Folsom, president of the Radio Corporation of America; T. Keith Glennan, president of Case Institute of Technology and a former member of the AEC; Samuel B. Morris, chief engineer of the Department of Water and Power for Los Angeles, and Walter P. Reuther, president of the United Automobile Workers.

Federal Science Budget

The U. S. Government will spend $2.6 billion on scientific research in 1957, if Congress accepts the Administration's budget recommendations. This represents an increase of 13 per cent over last year and 23 per cent over the year before.

The biggest backer of science will be the Defense Department. About $1.4 billion of the Department's $42.4 billion request is earmarked for research and development.

The Atomic Energy Commission plans to reduce slightly its expenditures for weapons research. But the $299 million allotted to nonweapon nuclear research is 38 per cent more than last year.

The National Science Foundation, which got $16 million last year, has asked for $42 million to support basic research. This total would include $18 million for the satellite project. While making his request, NSF board chairman Chester I. Barnard released the results of a survey by the Russell Sage Foundation. It showed that 43 large privately endowed foundations had supported only 1 per cent of the nation's scientific research and development in 1953. Underlining his budget proposal, Barnard said: "During recent months it has been quite evident in many ways that the promotion of science is not merely important but an urgent national problem."

Attachés Detached

A six-year-old science program in the State Department appears to be ending by default. This year, for the first time since 1950, no scientific attaché is serving at a U. S. embassy. In headquarters at Washington the post of Science Adviser has been vacant for more than 18 months. The Department's Science Office, which the adviser is supposed to direct, is being run by a nonscientist. So reports *Chemical & Engineering News*, the American Chemical Society weekly.

The attaché program, an outgrowth of the State Department's reorganization in 1949, was set up to keep the diplomatic service informed on scientific and technical matters affecting foreign relations. In 1952 there were 10 scientists on duty in five European embassies, and Joseph B. Koepfli, a chemist from the California Institute of Technology, was Science Adviser. When Koepfli left this post in 1954, no successor was appointed, and the terms of the last attachés ended in 1955.

Participating scientists were reportedly enthusiastic about the results of their efforts. They found wide acceptance among colleagues in foreign countries, and were called upon to perform an increasing variety of useful liaison jobs. According to *C & E News*, these men feel that to let the program die now "would be next to criminal and an enormous waste of their time and the taxpayers' money."

University of Science

A new university which awards just two degrees, the Ph.D. and Sc.D., has been established in New York as part of the Rockefeller Institute for Medical Research. The purpose of the school is to provide at least three years of advanced training for a select group of scholars in the natural sciences.

Backed by the Institute's $150 million endowment, the new university will be

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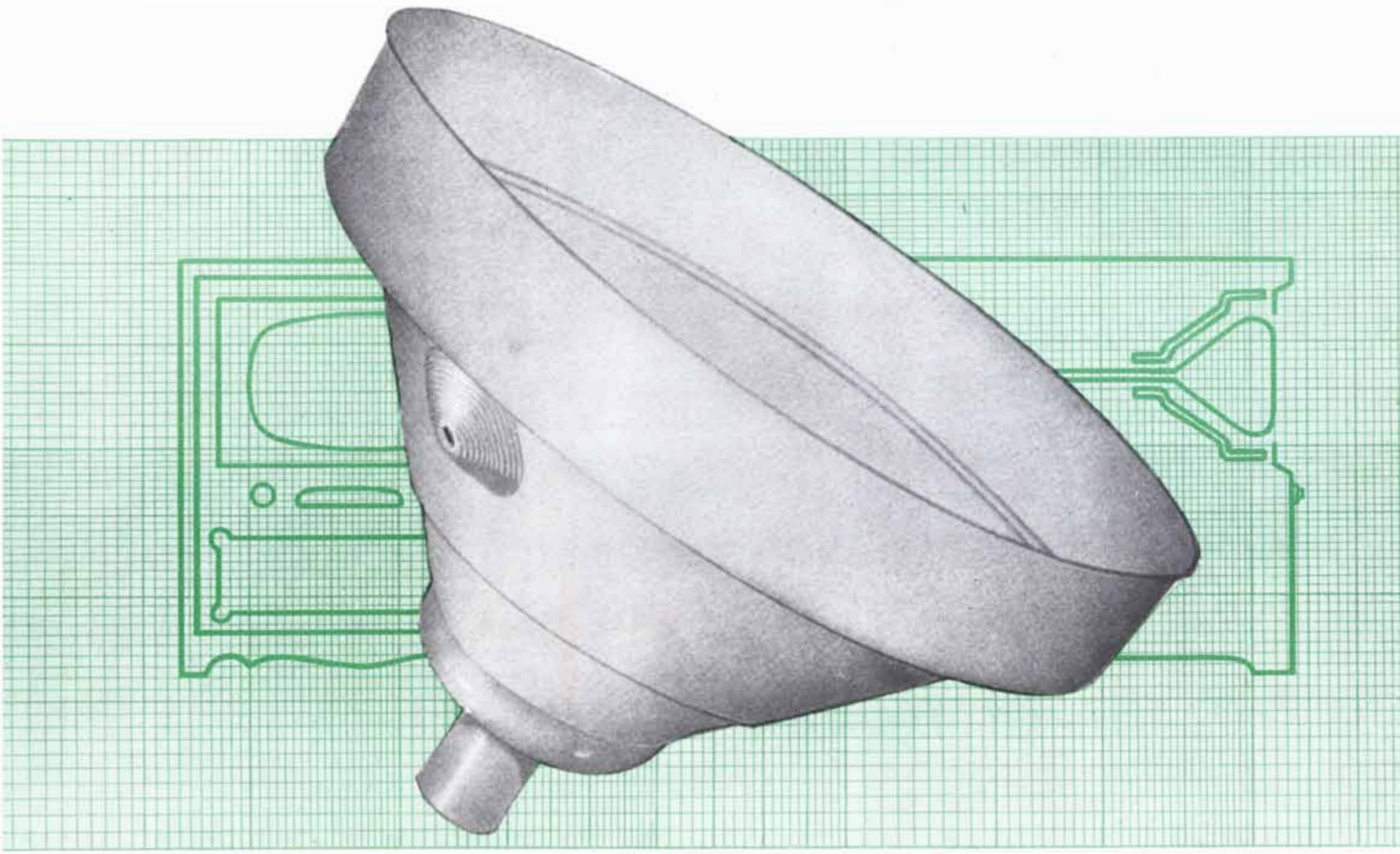

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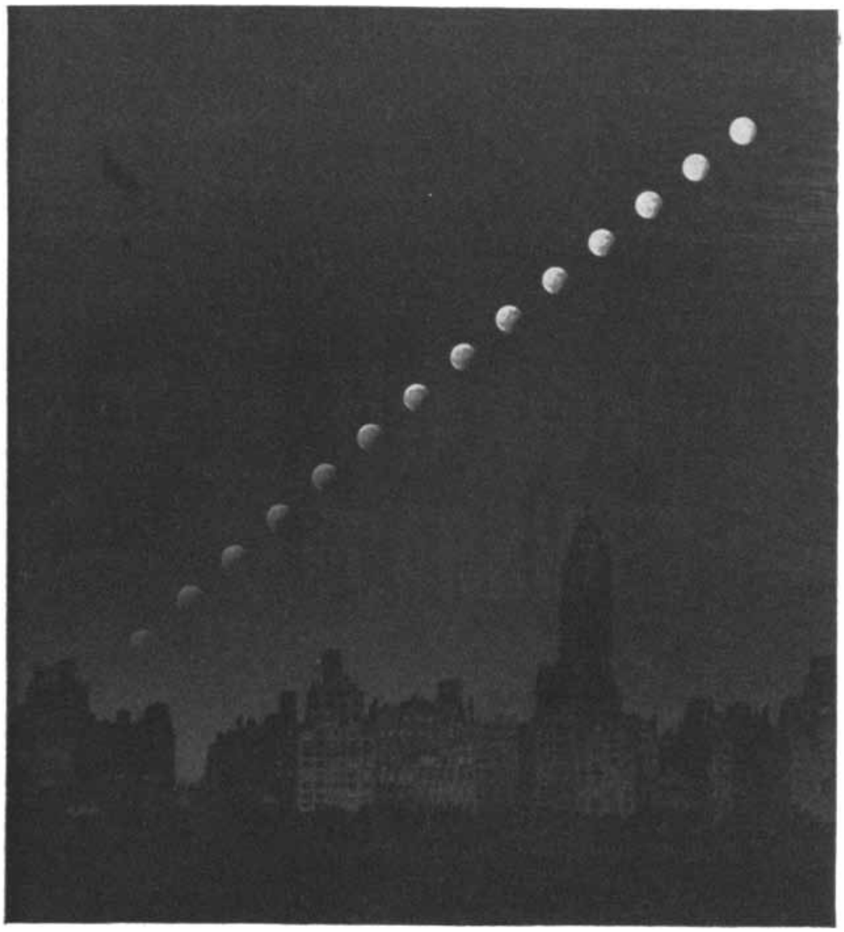


the third wealthiest in the world, after Harvard and Yale. The per capita endowment will be enormous, for the student enrollment will be limited to 75.

The educational program will be lavish, according to president Detlev W. Bronk's description. The faculty will include, besides 150 scientists of the Institute's staff, distinguished visiting lecturers, each of whom will spend a week with the students. Among the lecturers already appointed are I. I. Rabi of Columbia, J. G. Kirkwood of Yale, William Robbins of the New York Botanical Garden, Lord Adrian of Cambridge, Alexander Monnier of the Sorbonne, Alexandre von Muralt of Berne and Ragnar Granit of Stockholm.

Each member of the student body will receive an annual stipend of $2,500 to defray the cost of his studies. As he develops specialized interests, he will be urged to spend part of this time studying under leading scholars in other universities, anywhere in the world. The Institute will pay for this travel and study. It hopes to foster closer cooperation among universities by this arrangement.

The Institute last fall enrolled an experimental class of one woman and nine men, graduates of various universities, including one from Oslo. Each year the university plans to build up its enrollment by choosing 15 to 20 more graduates. Those who have majored in the sciences will work toward the Ph.D. degree. Some who have already received M.D.'s will become Doctors of Medical Science.

The physical facilities include almost half a million square feet of well-equipped laboratory space, a hospital for the study of diseases and a large scientific library. To these the Institute plans to add still more laboratories and a residence hall.

A.A.A.S. Segregation Vote

The American Association for the Advancement of Science last month announced the vote of its executive council members on the question of barring national meetings of the Association in cities practicing racial segregation. The mail-ballot vote was 219 to 28 for the resolution not to meet in such cities in the future.

Science Teacher Reserve

A novel plan for increasing the supply of science teachers was proposed last month by David Sarnoff, chairman of the board of the Radio Corporation of America. Engineers and scientists em-

ployed by industry, he suggested, should be given leaves of absence of at least a year at full pay to teach in their local high schools. They would be members of a reserve corps legally recognized by an act of Congress. Other recruits to the reserve might come from industrial scientists who have retired or who are willing to teach in night schools while continuing their regular work.

Sarnoff outlined the plan at a meeting of the National Security Industrial Association, an organization set up to encourage government-industry cooperation in matters affecting national security.

Amateur Satellists

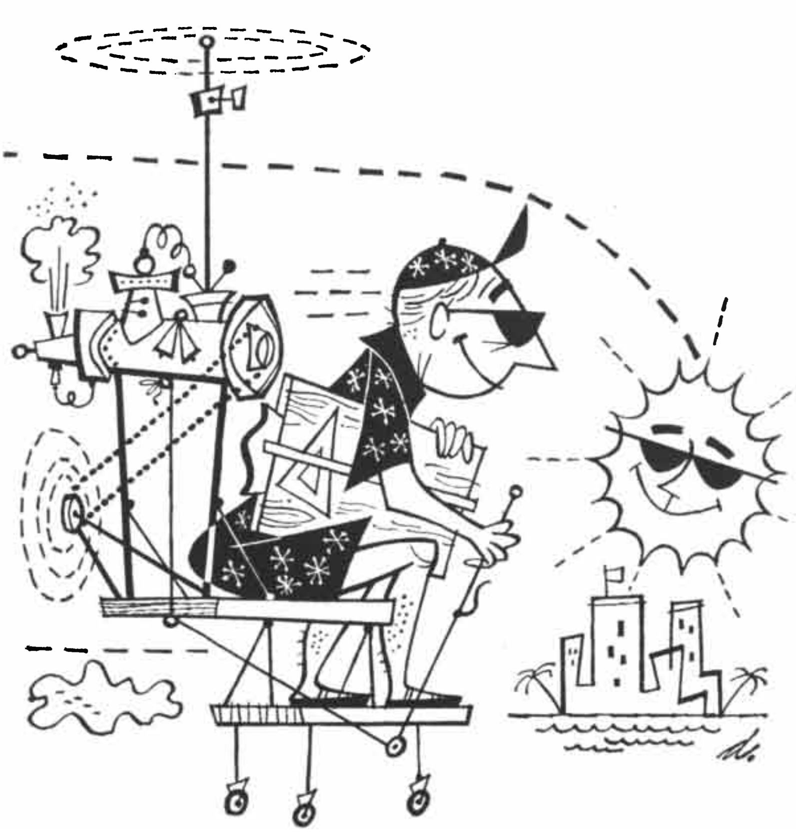
Amateur astronomers will play an important role in the earth satellite program of the 1957-58 International Geophysical Year. They are to be enlisted to help professionals plot the flight path of each satellite, Fred L. Whipple of Harvard University, director of the Smithsonian Astrophysical Observatory, told a New York meeting of the Institute of the Aeronautical Sciences.

Amateurs in each area will be organized under a group captain. They will fix their telescopes or binoculars on a known star, and when the satellite flies by, they will tell the captain at what time it passed and where it was in relation to the star. Radio "hams" can help relay this information to centers where the satellite's orbit will be computed.

More information has been forthcoming about the launching and the orbits of the U. S. satellites. The first flights will take off eastward from Patrick Air Force Base halfway down the coast of Florida. They will follow an elliptical path slightly inclined to the plane of the earth's equator. Thus from the earth they will appear to weave along a 5,000-mile-wide band, ranging roughly between 40 degrees North and South latitudes. The satellites should be observable in the U. S., Central and South America, Africa, Southern Europe, the Balkans and the Middle East, part of the Soviet Union, Pakistan, India, China, Japan, Indonesia, Australia and New Zealand.

Old Air in Ice

On close examination it is obvious that icebergs are not just plain ice. They are white, whereas ordinary ice in bulk is bluish. A piece of iceberg in a pail of water fizzes as it melts. The reason for all this is that icebergs are shot through with tiny air bubbles under pressure. Three oceanographers who have studied



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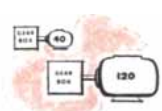

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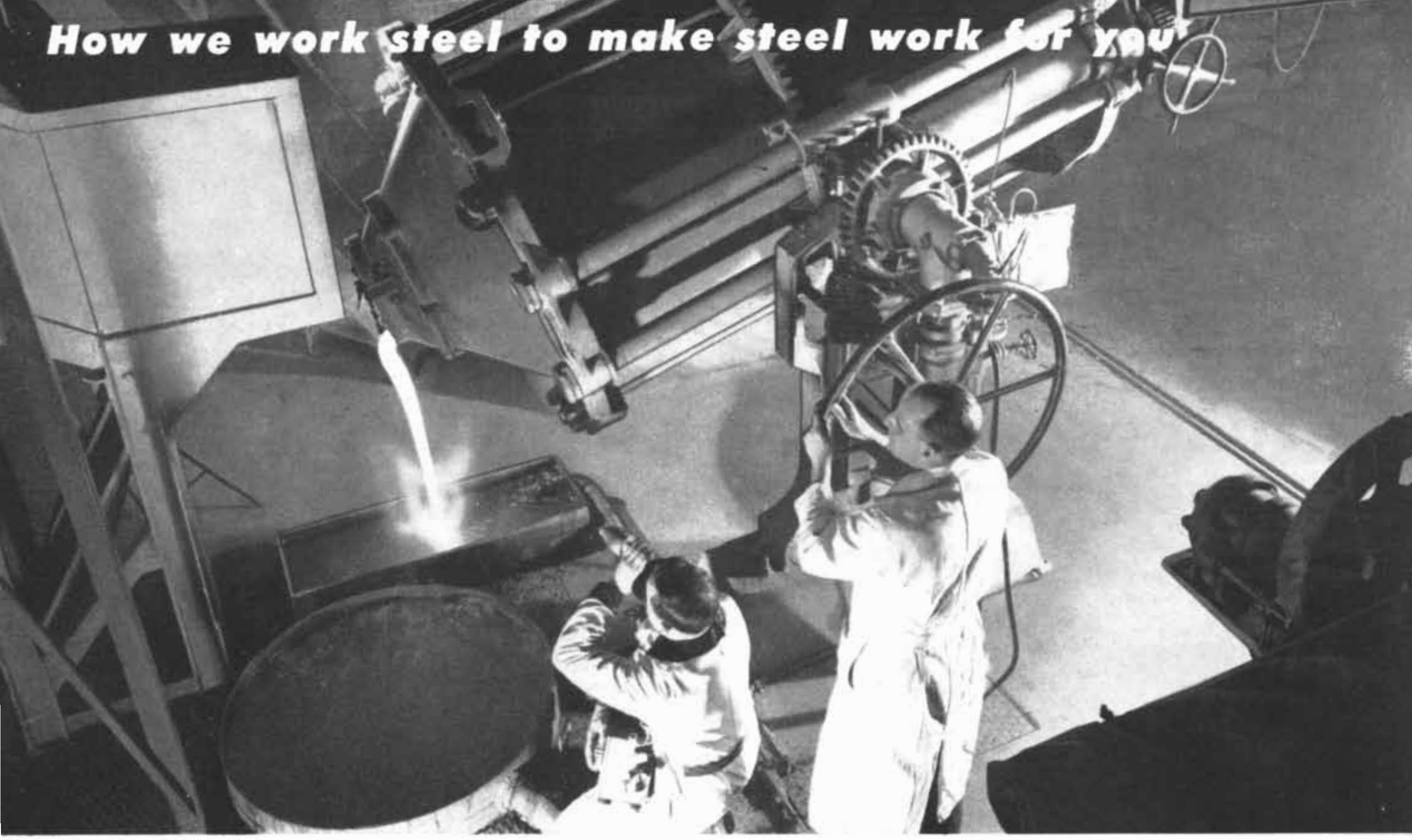

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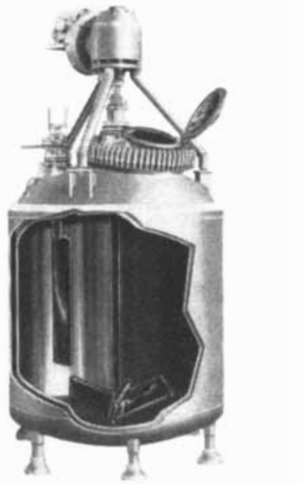

Glascote produces a complete line of glass-on-steel equipment for the process industries—storage tanks and vessels, reactors (shown here), condensers, heat exchangers, pipe and columns.

Perfected by A. O. Smith research — More than 3000 formulae for glass have been developed and tested by A. O. Smith to create the *thirteen* special kinds that now give corrosion-protection to a wide range of steel products.

Just for example, consider the corrosion problems in the chemical processing industry. Here, equipment must withstand continuous attack by acids and alkalis . . . must also resist quick, punishing changes in temperature. Here, Glascote Products, Inc., an A. O. Smith subsidiary, is widely recognized for glass-lined equipment that excels in severest corrosive service.

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the matter believe that the air was trapped when the ice was originally formed by compression of snow. They have been analyzing the air as samples of the atmosphere prevailing at the time.

P. F. Scholander, John W. Kanwisher and D. C. Nutt, members of an arctic expedition from the Woods Hole Oceanographic Institution in 1954, examined samples from six icebergs. In four the oxygen content was the same as in today's atmosphere, but in the other two it was significantly lower. The oceanographers, reporting their work in *Science*, suggest that the latter icebergs may have been formed during the last ice age, when there was less green vegetation on the earth and less production of oxygen.

Xeroradiography

Erasable X-ray pictures are printed in a new machine developed by the General Electric Company. The process, called xeroradiography, utilizes aluminum plates coated with selenium instead of the usual photographic emulsion. The plates need not be stored in lead boxes to avoid premature exposure, nor do they require water and chemicals for development.

Before being exposed, the surface of a plate is electrostatically charged. Then X-rays striking various areas wipe off an amount of charge proportionate to the radiation intensity. Powder dusted on the exposed plates adheres densely to the strongly charged areas, only scantily to those that have been most discharged. The result is a three-dimensional picture in powder. It is finished in about 40 seconds after exposure. The pictures show cartilage, tendons and muscles as well as bone.

New Light on Protein-Making

An important fact concerning the role of ribonucleic acid (RNA) in the synthesis of proteins [*see Ernest F. Gale's article on page 44 of this issue*] has been established by experimenters at the University of California. Testing the theory that RNA is manufactured in the nucleus of the cell and then moves out to the cell's cytoplasm, where it presumably controls the production of protein, they have proved that the RNA in the cytoplasm actually does come from the nucleus.

Lester Goldstein and Walter S. Plaut at Berkeley raised some amoebae on a diet containing radioactive phosphorus. The cells incorporated the phosphorus atoms into RNA in their nuclei. Then the experimenters transplanted the "hot" nuclei into ordinary amoebae whose own nuclei had been removed. After five hours the radiophosphorus appeared in the cytoplasm of these hybrid cells, and all the activity was proved to come from RNA. The biochemists also were able to demonstrate that there is no reverse traffic of RNA back to the nucleus.

Blood Technology

Biologists nowadays solve dilemmas even more delicate than Shylock's. The latest stunt is the removal of plasma from a donor's blood while letting him keep the other blood fractions.

A group at Children's Hospital in Philadelphia has been bleeding donors every other week without ill effects. The blood is removed and centrifuged in the blood fractionator developed under the late Edwin Cohn of Harvard University. Then all but the plasma is returned to the donor's body. The entire process takes just 22 minutes.

Joseph Smolens reported the work at the Tenth Conference on the Plasma Proteins and Cellular Elements of the Blood. The donors are persons who have acquired immunity to mumps or whooping cough, and their plasma is rich in antibodies. Even after repeated bleedings their immunity is undiminished. Joseph Stokes, Jr., another leader of the project, said that biweekly bleedings of 2,000 selected donors could provide as much disease-fighting plasma as is now obtained from four million donors bled once a year.

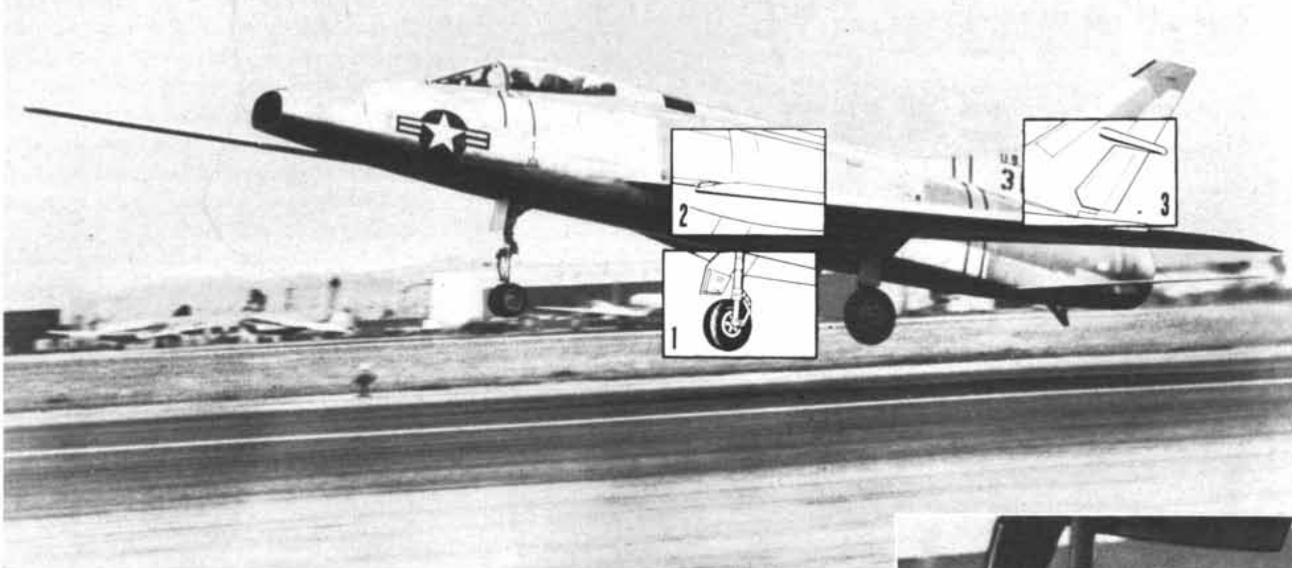
An improved method of preserving whole blood is reported by Harold T. Meryman of Yale Medical School and Emanuel Kafig of the Naval Medical Research Institute in the current issue of *Proceedings of the Society for Experimental Biology and Medicine.* They spray blood on the surface of a pool of liquid nitrogen. The blood droplets, suddenly chilled to 195 degrees below zero centigrade, freeze instantly into small grains. These are skimmed off and can be stored indefinitely, as long as they are kept extremely cold. When needed for transfusion, they are thawed in a warm salt solution.

ESP Debate

Extrasensory perception (ESP) does not often reach a forum for serious debate among scientists, but readers of *Science* were recently treated to a rare display of arguments—and tempers—on the subject.

In a nine-page article in the weekly

CPT Creative Pioneers in Transport



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Pioneer in landing gear development since 1926, CPT has produced more landing gears than any other manufacturer.

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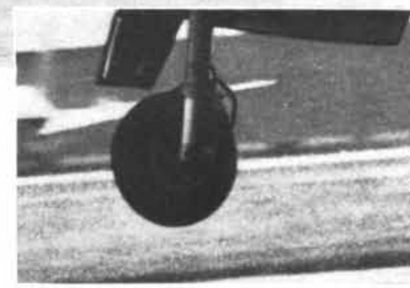

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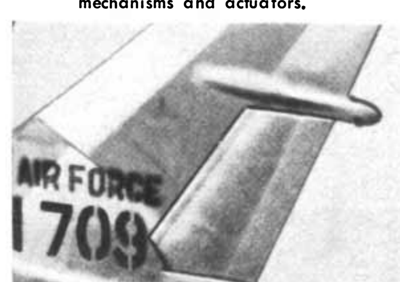

3 **FIN BEAMS**—High-strength, lightweight fin beams are made by CPT, using the world's largest flash-butt welder for assembly.

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last summer, George R. Price of the University of Minnesota attacked the notion of ESP and criticized the methods of S. G. Soal of London and J. B. Rhine of Duke University, the principal investigators of parapsychology. Price based his arguments largely on the reasoning of David Hume. He is not willing to believe in ESP until evidence of its existence outweighs evidence in favor of the natural laws with which ESP seems incompatible. Price went on to suggest that Rhine and Soal might have got positive results through fraud. And he challenged them to test ESP under rigorous conditions he specified.

A free-for-all followed several weeks ago in an issue of *Science* devoted largely to the pros and cons of parapsychology. Soal and Rhine each countered Price's arguments. They were backed by two of Price's own colleagues, Michael Scriven and Paul E. Meehl of the Minnesota psychology department. Price followed with a rebuttal, and Rhine rebutted him.

In the midst of this wrangle the Harvard University physicist and philosopher of science Percy W. Bridgman inserted a fresh note. He is willing to accept both Hume's reasoning and the honesty of leading parapsychologists in reporting their experimental results. But Bridgman still doubts that ESP can be proved by the fact that certain people are able to guess the symbols on a card with unusual frequency.

Bridgman believes that the use of probability laws in science needs restudy. He calls attention to Bertrand Russell's paradox that "we encounter a miracle every time we read the license number of a passing automobile" because the odds are millions to one against our encountering that particular number. In short, if something highly improbable happens, it proves only that the highly improbable has happened; it does not necessarily prove the existence of a phenomenon for which there is no corollary support.

In conclusion Bridgman offers a broad challenge to scientific philosophers: "The situation covered by the word *probability* is a desperately complex situation, mostly of our own making and in our own minds, with a fragile and fleeting dependence on time, and never coherently connected with concrete 'objective' events.

"I personally can now see so much here that needs to be thrashed out and clarified that I am unwilling to accept the genuineness of any phenomenon that leans as heavily as does ESP on probability arguments."

stretch

Originally created to help spin better yarn, unique material now solves many drive-belt problems

It looks like an ordinary rubber band. Feels like one, too. But there the similarity ends, because this rubber band won't stretch . . . which is one of the big reasons why it's so useful.

Its story starts back in the middle thirties, when Armstrong research chemists began development work on a new kind of apron for the textile industry. (Aprons look much like two-inch-wide rubber bands, but they actually help to control fibers on a yarn-spinning frame.)

The researchers knew what they wanted in an apron—flexibility, oil resistance, proper frictional "grip," freedom from seams, precise dimensions—all this with absolutely no stretch. But they also knew there was no existing material that combined all these qualities. The problem, then, was to create such a material.

Armstrong chemists felt that synthetic rubber, with its great flexibility and oil resistance, would probably be a good basic material—if they could keep it from stretching. After much experimentation, they found the answer by vulcanizing a sturdy cord interliner between two layers of tough synthetic rubber. The result: a rubber band that didn't stretch. And since the vulcanization literally fused the layers of this "sandwich" together, there were no seams to worry about, either.

The next—and last—step was to make sure that this unusual rubber band had exactly the right frictional grip. This presented a knotty problem because normally synthetic rubber has too much surface friction to serve as an apron . . . it grabs too hard. A controlled reduction of the friction was finally achieved, though, by giving the bands a series of special chemical baths which changed the character of the surface molecules.

These synthetic rubber aprons soon became the standard in the textile field. And as their reputation grew, other applications began to appear. A dictating machine manufacturer, for example, realized that the same qualities which made for good apron performance were just what he had been looking for in a small power transmission belt. And so this very special rubber band—in this case only ⅜ of an inch wide—went to work driving an electronic dictating machine.

Still another application for these bands was found by a package machinery builder who uses much wider ones as conveyor belts. Right now, these bands are being tested for postage meters, automatic duplicating equipment, and tape recorders. The future? It looks bright for this rubber band that won't stretch.

If you manufacture equipment that uses—or could use—flat belt drives, these non-stretch seamless belts may open the way to lower costs or improved performance. They're available in many different sizes. For suggestions concerning specific applications, write to Armstrong Cork Company, Industrial Division, 8203 Inland Road, Lancaster, Penna.

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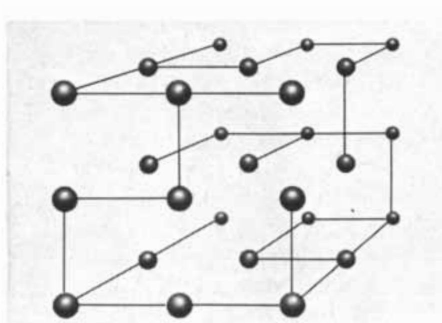
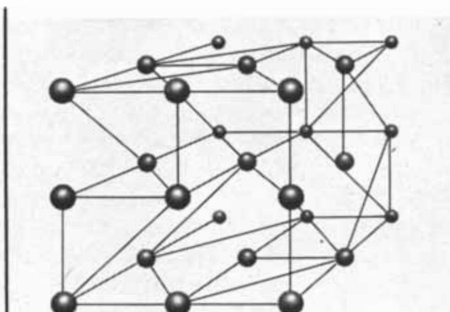


THE MOLECULES in resilient synthetic rubber are not completely cross-linked. Although the surface is smooth, its coefficient of friction is relatively high—a desirable characteristic for many drive belt applications.



FOR TEXTILE APRONS, a lower coefficient of friction is desired. To get it, Armstrong chemists developed a special chemical bath that oxidizes the rubber, creating a denser surface with considerably lower friction.

WORLD POPULATION

After an extended trip around the world, an eminent biologist discusses the present status of the race between the increase in the number of people and the rise of their food production

by Julian Huxley

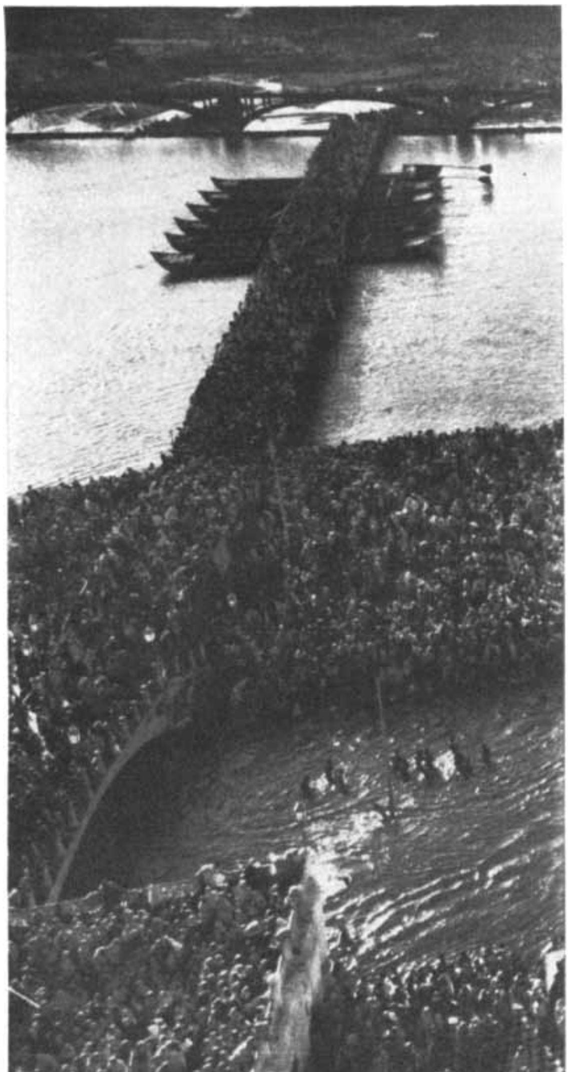
The problem of population is the problem of our age. In the middle of the 20th century anyone who travels around the world, as I have recently done, cannot fail to be struck by the signs of growing pressure of population upon the resources of our planet. The traveler is impressed by the sheer numbers of people, as in China; by the crowding of the land, as in Java; by the desperate attempts to control population increase, as in Japan and India; and at the same time by the erosion, deforestation and destruction of wildlife almost everywhere. The experiences of travel merely highlight and illustrate a fact which for some time has been obtruding itself on the world's consciousness: that the increase of human numbers has initiated a new and critical phase in the history of our species.

This crisis was recognized by the holding of a Conference on World Population in Rome in 1954. Held under the aegis of the United Nations, the Conference was a milestone in history, for it was the first official international survey of the subject of human population as a whole. In 1949 the UN had convened a scientific conference on world resources at Lake Success. As Director General of UNESCO, invited to collaborate in this project, I had suggested that a survey of resources should be accompanied by a similar survey of the population which consumed the resources. I was told that there were technical, political and religious difficulties. Eventually these difficulties were smoothed over; censuses were taken; and a conference on population was duly held in 1954. During the five years it took to arrange for a look at the problem the world population had increased by more than 130 million.

Let me begin by setting forth some of the facts—often surprising and sometimes alarming—which justify our calling the present a new and decisive phase in the history of mankind. The first fact is that the total world population has been increasing relentlessly, with only occasional minor setbacks, since before the dawn of history. The second fact is the enormous present size of the population —more than 2.5 billion. The third is the great annual increase: some 34 million people per year, nearly 4,000 per hour, more than one every second. The human race is adding to its numbers the equivalent of a good-sized town, more than 90,000 people, every day of the year. The fourth and most formidable fact is that the rate of increase itself is increasing. Population, as Thomas Malthus pointed out in 1798, tends to grow not arithmetically but geometrically—it increases by compound interest. Until well into the present century the compound rate of increase remained below 1 per cent per annum, but it has now reached 1⅓ per cent per annum. What is more, this acceleration of increase shows no sign of slowing up, and it is safe to prophesy that it will continue to go up for at least several decades.

In short, the growth of human population on our planet has accelerated from a very slow beginning until it has now become an explosive process. Before the discovery of agriculture, about 6,000 B.C., the total world population was probably less than 20 million. It did not pass the 100 million mark until after the time of the Old Kingdom of Egypt, and did not reach 500 million until the latter part of the 17th century. By the mid-18th century it passed the billion mark, and in the 1920s it rose above two billion. That is to say, it doubled itself twice over in the period between 1650 and 1920. The first doubling took nearly two centuries, the second considerably less than one century. Now, at the present rate of acceleration, the population will have doubled itself again (from the 1920 figure) by the early 1980s—*i.e.*, in the amazingly short space of 60 years.

Each major upward step in numbers followed some major discovery or invention—agriculture, the initiation of urban life and trade, the harnessing of non-human power, the technological revolu-



HUGE CROWD of Indians was photographed in 1950 during the Kumbh-Mela, a tion. During the present century the most decisive factor in increasing population has been of a different sort—the application of scientific medicine, or what we may call death control. In advanced countries death rates have been reduced from the traditional 35 or 40 per thousand to less than 10 per thousand. The average life span (life expectancy at birth) has been more than doubled in the Western world since the mid-19th century. It now stands at about 70 years in Europe and North America, and the process of lengthening life has begun to get under way in Asian countries: in India, for example, the life expectancy at birth has risen within three decades from 20 to 32 years.

Birth Rates *v.* Death Rates

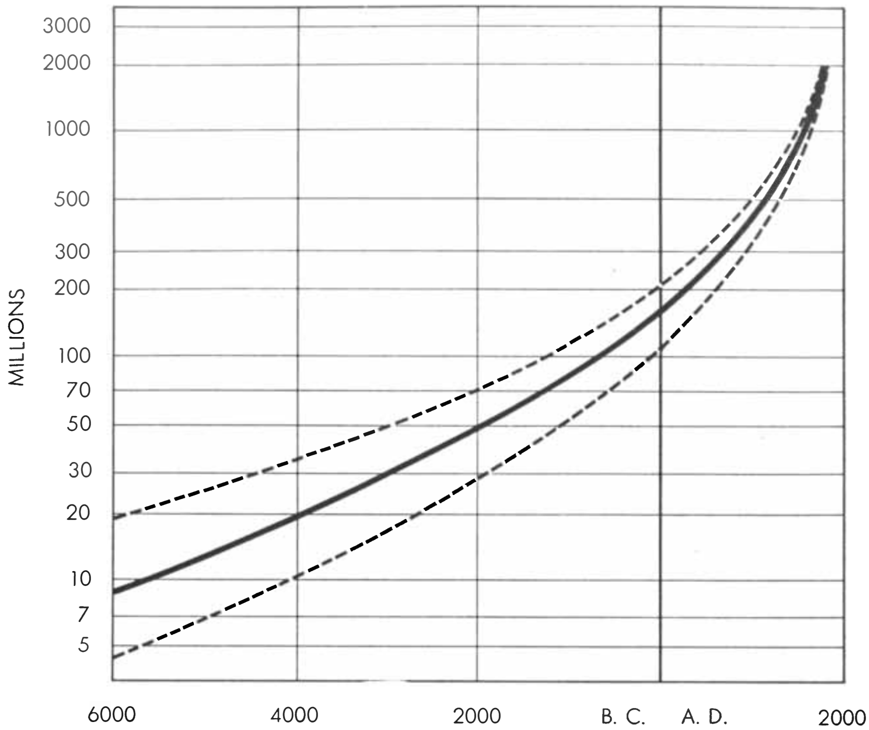
Population growth appears to pass through a series of stages. In the first stage both the birth rate and the death rate are high, and the population increases only slowly. In the second stage the death rate falls sharply but the birth rate stays high; the population therefore expands more or less explosively. In the third, the birth rate also falls sharply, so that the increase of population is slowed. Finally both the birth and the death rates stabilize at a low figure; thereafter the population will grow only slowly unless it is spurred by some new development, such as access to new food sources or a change in ideas and values.

In the Western world the reduction of the death rate came gradually, and its effect on population growth was buffered by factors which tended at the same time to reduce the birth rate—namely, a rising standard of living and industrialization, which made children no longer an economic asset.

Matters have been very different in the still underdeveloped countries of Asia. There death control has been introduced with startling speed. Ancient diseases have been brought under control or totally abolished in the space of a few decades or even a few years. Let me give one example. In England malaria took three centuries to disappear; in Ceylon it was virtually wiped out in less than half a decade, thanks to DDT and a well-organized campaign. As a result of this and other health measures, the death rate in Ceylon was reduced from 22 to 12 per thousand in seven years—a fall which took exactly 10 times as long in England. But the Ceylon birth rate has not even begun to drop, and so the population is growing at the rate of 2.7 per cent per annum—about twice the highest rate ever experienced in Britain. If this rate of growth continues, the population of Ceylon will be doubled in 30 years.

Almost all the underdeveloped countries are now in this stage of explosive

religious festival during which Hindus bathe in the Ganges. At the Kumbh-Mela of 1954 the author witnessed a crowd estimated at four and a half million. This photograph was made by *Life* photographer David Douglas Duncan. Copyright 1950 by Time, Inc.



WORLD POPULATION GROWTH since 6000 B. C. is traced in this chart by the heavy curve. The curves above and below it represent upper and lower limits of the estimate.

expansion. When we recall that rates of expansion of this order (2 to 3 per cent) are at work among more than half of the world's 2.5 billion inhabitants, we cannot but feel alarmed. If nothing is done to control this increase, mankind will drown in its own flood, or, if you prefer a different metaphor, man will turn into the cancer of the planet.

Malthus, a century and a half ago, alarmed the world by pointing out that population increase was pressing more and more insistently on food supply, and if unchecked would result in widespread misery and even starvation. In recent times, even as late as the 1930s, it had become customary to pooh-pooh Malthusian fears. The opening up of new land, coupled with the introduction of better agricultural methods, had allowed food production to keep up with population increase and in some areas even to outdistance it. During the 19th century and the early part of the 20th food production increased in more than arithmetical progression, contrary to the Malthusian formula. We now realize, however, that this spurt in food production cannot be expected to continue indefinitely: there is an inevitable limit to the rate at which it can be increased. Although Malthus' particular formulation was incorrect, it remains true that there is a fundamental difference between the increase of population, which is based on a geometrical or compound-interest growth mechanism, and the increase of food production, which is not.

There are still some optimists who proclaim that the situation will take care of itself, through industrialization and through the opening of new lands to cultivation, or that science will find a way out by improving food-production techniques, tapping the food resources of the oceans, and so on. These arguments seem plausible until we begin to look at matters quantitatively. To accelerate food production so that it can keep pace with human reproduction will take skill, great amounts of capital and, above all, time—time to clear tropical forests, construct huge dams and irrigation projects, drain swamps, start large-scale industrialization, give training in scientific methods, modernize systems of land tenure and, most difficult of all, change traditional habits and attitudes among the bulk of the people. And quite simply there is not enough skill or capital or time available. Population is always catching up with and outstripping increases in production. The fact is that an annual increase of 34 million mouths to be fed needs more food than can possibly go on being added to production year after year. The growth of population has reached such dimensions and speed that it cannot help winning in a straight race against production. The position is made worse by the fact that the race isn't a straight one. Production starts far behind scratch: according to the latest estimates of the World Health Organization, at least two thirds of the world's people are undernourished. Production has to make good this huge deficiency as well as overtake the increase in human numbers.

A Population Policy

Is there then no remedy? Of course there is. The remedy is to stop thinking in terms of a race between population and food production and to begin thinking in terms of a balance. We need a population policy.

The most dangerous period lies in the next 30 or 40 years. If nothing is done to bring down the rate of human increase during that time, mankind will find itself living in a world exposed to disastrous miseries and charged with frustrations more explosive than any we can now envision.

Even primitive societies practice some form of population control—by infanticide or abortion or sexual abstinence or crude contraceptives. Since the invention of effective birth control methods in the 19th century, they have been very generally practiced in all Western countries. Their spread to other cultures has been retarded by various inhibitions—religious, ideological, economic, political. It is worth noting that one retarding factor in the past has been the reluctance of colonial powers to encourage birth control in their colonies, often out of fear that they might be considered to be seeking to use population control as a weapon against an "inferior" race.

Today the underdeveloped countries are making their own decisions; what is needed is a new and more rational view of the population problem everywhere. We must give up the false belief that mere increase in the number of human beings is necessarily desirable, and the despairing conclusion that rapid increase and its evils are inevitable. We must reject the idea that the quantity of human beings is of value apart from the quality of their lives.

Overpopulation—or, if you prefer, high population density—affects a great many other needs of mankind besides bread. Beyond his material requirements, man needs space and beauty, recreation and enjoyment. Excessive population can erode all these things. The rapid population increase has already created cities so big that they are beginning to defeat their own ends, producing discomfort and nervous strain and cutting off millions of people from any real contact or sense of unity with nature. Even in the less densely inhabited regions of the world open spaces are shrinking and the despoiling of nature is going on at an appalling rate. Wildlife is being exterminated; forests are being cut down, mountains gashed by hydroelectric projects, wildernesses plastered with mine shafts and tourist camps, fields and meadows stripped away for roads and aerodromes. The pressure of population is also being translated into a flood of mass-produced goods which is washing over every corner of the globe, sapping native cultures and destroying traditional art and craftsmanship.

The space and the resources of our planet are limited. We must set aside some for our material needs and some for more ultimate satisfactions—the enjoyment of unspoiled nature and fine scenery, satisfying recreation, travel and the preservation of varieties of human culture and of monuments of past achievement and ancient grandeur. And in order to arrive at a wise and purposeful allocation of our living space we must have a population policy which will permit the greatest human fulfillment.

If science can be applied to increase the rate of food production and to satisfy our other needs, it can and should also be applied to reduce the rate of people production. And for that, as for all scientific advance, we need both basic research and practical application. Basic research is needed not only on methods of birth control but also on attitudes toward family limitation and on population trends in different sections of the world. Once we have agreed on the need for a scientific population policy, the necessary studies and measures to be applied will surely follow. This does not mean that we should envisage a definite optimum population size for a given country or for the world as a whole. Indeed, to fix such a figure is probably impossible, and to use it as a definite target is certainly impracticable. For the time being our aim should be confined to reducing the over-rapid population growth which threatens to outstrip food supply. If we can do this, our descendants will be able to begin thinking of establishing a more or less stable level of population.

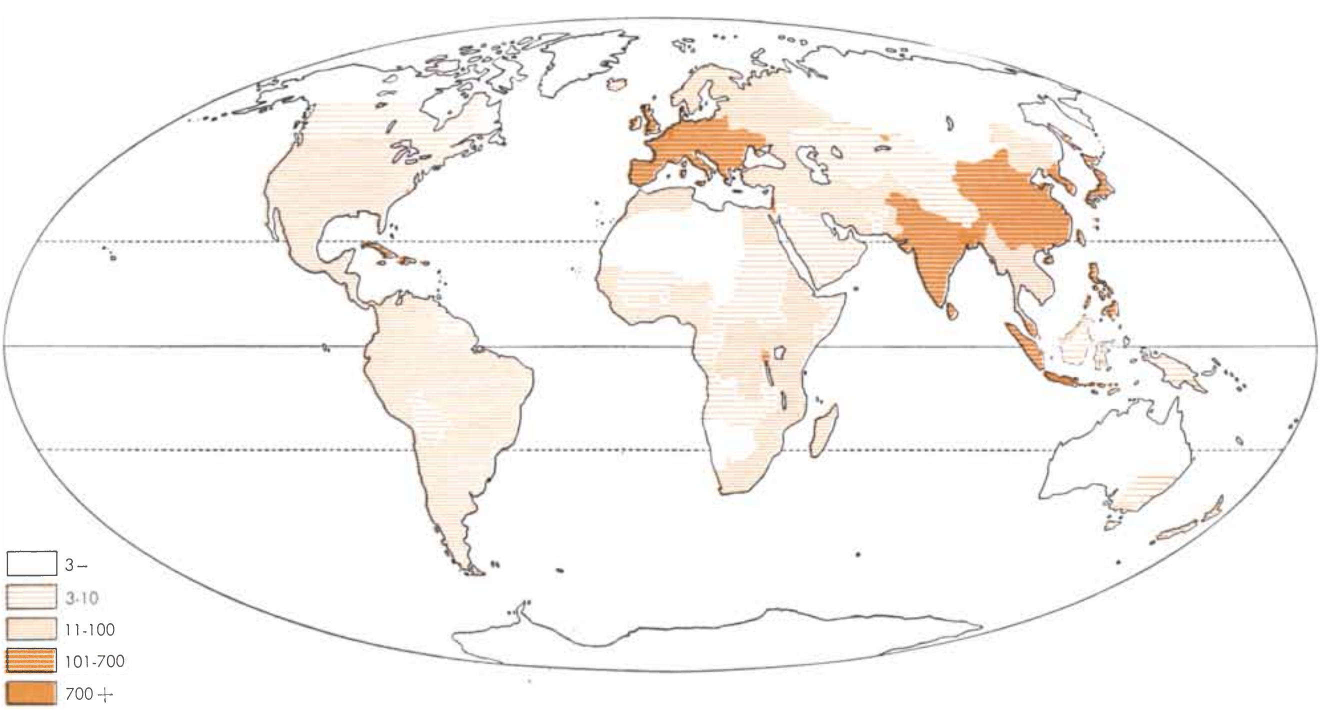
Japan and India

With these general observations as our guide, we can now get a clearer grasp of the population problems of individual countries. Since the end of World War II, we have seen a new phenomenon in the world's history. Two great and powerful nations, India and Japan, have officially adopted the policy of population control.

Japan I was unable to visit, but its demographic plight is so extreme and so illuminating that I shall take it first. Japan's 90 million people are crowded into an area only one and one-half times as large as the small British Isles. The country is so mountainous that it affords only one seventh of an acre of cultivable land per head. And its population is increasing by more than 1 per cent per annum, so that within 10 years it will easily overshoot the 100-million mark.

The Japanese are not well nourished: the average daily calorie intake is only 2,000. About one fifth of this meager food supply must be imported, despite the fact that the Japanese have developed the highest rice yield per acre in Asia. Since the war lost them their empire, and the isolation of Communist China deprived them of their biggest market, the Japanese have been able to subsist only through aid given by the U. S. As a recent report on World Population and Resources by the Political and Economic Planning (P.E.P.) organization in Britain says: "Japan is undoubtedly the most overpopulated great country there has ever been."

Realizing that no expansion of its industry and trade could possibly take care of a major increase in its population, the Japanese Government has embarked on



DENSITY OF POPULATION in various parts of the world is indicated in this map. The numbers beside the key at the left represent the number of people per square mile. In most cases the population density has been averaged within political boundaries.

a firm policy of population control. In Japan infanticide was widely practiced until some 80 years ago. As its first move after the recent war the Government turned to an almost equally desperate measure: it legalized and indeed encouraged abortion. The number of induced abortions rose from a quarter of a million in 1949 to well over a million in 1953. As was to be expected, the effects on the health of Japanese women were deplorable—and the annual percentage rate of population increase was still above the prewar level.

With these stark facts in mind, the Japanese Ministry of Health's Institute of Population Problems in 1954 passed a strong resolution urging government encouragement of contraception. It proposed that birth-control facilities be provided as part of the health services, that medical schools pursue research and include family planning in the curriculum, that doctors called upon to induce an abortion should be required to provide the woman with information about birth control for the future and that national wage and taxation policies should be such as to avoid "encouraging large families."

Drastic though these recommendations are, they or something very like them are necessary, and it is much to be hoped that they will be speedily and thoroughly implemented. If they are successfully put into practice, they will not only save Japan from disaster but will provide valuable lessons for other countries.

India's problem is rather different. It is an immense country—the best part of a subcontinent—with large resources waiting to be developed. Its present rate of population increase is just under 1⅓ per cent per annum—lower than that in the U. S. (which is 1.6 per cent, excluding immigration). Its immediate future is not quite as desperate as Japan's.

But India is still in the early expanding stage of the population cycle. Its death rate (now about 26 per thousand) has just begun to fall, and has a long way to go before it drops to that of advanced countries. Meanwhile its birth rate (about 40 per thousand according to the latest available figures) is well over double that in Western Europe, and shows no signs of dropping. If the death rate is cut to the extent that the Ministry of Health expects, and if the birth rate remains at its present level, within a few years India's annual increase of population will be some eight million—equivalent to adding a new London each year!

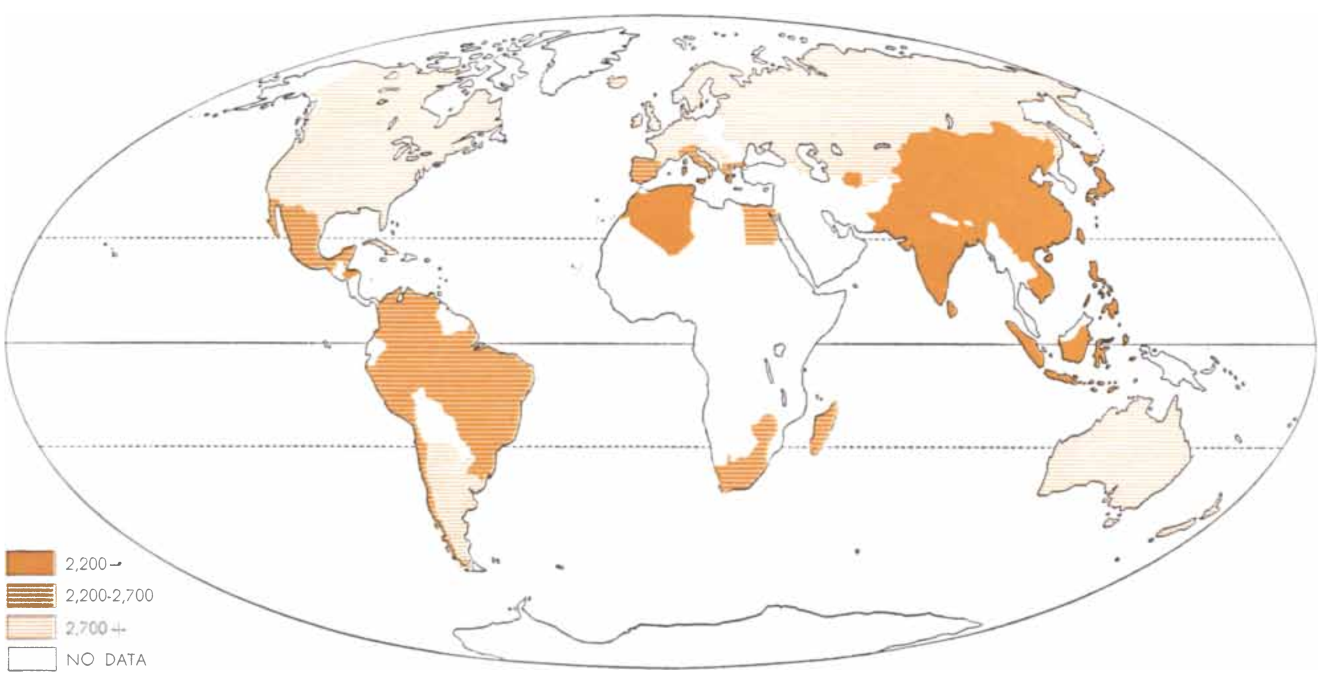
Moreover, India's population even now is not far from the borders of starvation; it must increase its food production drastically to achieve the barest minimum of decent living for its people. Their average daily diet is a mere 1,590 calories. At least two thirds of India's 380 million people are undernourished. Methods of cultivation and systems of land tenure are primitive and will need a painful and difficult process of improvement before they begin to satisfy modern requirements. Tradition, taboos, ignorance and illiteracy are grave obstacles to progress. Comparatively little more land could fruitfully be brought into cultivation, and deforestation compels the people to burn cow manure as fuel, thus robbing the soil of fertilizer.

Above all, the mere size of the problem is formidable. Even at the present rather modest rate of increase, five million people are added each year.

India's Masses

The size of India's human flood was forcibly brought home to me in 1954 when I visited the ill-fated Kumbh-Mela of that year. This religious festival is held at the junction of the two great rivers, the Jumna and the Ganges, at Allahabad. The assembled pilgrims acquire merit and salvation by bathing in the rivers' sacred waters. Every 12th year the festival is especially sacred, and the Kumbh-Mela of 1954 was uniquely important as being the first of these high points to occur after India's independence. One day of the festival is particularly auspicious and to bathe on that day is especially efficacious.

Pilgrims had converged from all over India—by train, by cart and by shanks'



NUMBER OF CALORIES per person per day is plotted on the same projection. The minus sign in the key indicates less than 2,200 calories; the plus sign, more than 2,700 calories. The dotted lines are the Tropic of Cancer and the Tropic of Capricorn.

mare. On the day we arrived, two and a half million people were encamped on the flats by the river, and three days later, on the great day of the festival, the number had grown to four and a half million! I shall never forget the spectacle of this enormous human ant heap, with its local condensations of crowds converging onto the temporary pontoon bridges over the Jumna to reach the sacred bathing grounds. A crowd of this magnitude makes a frightening and elemental impression: it seems so impersonal and so uncontrollable. This impression was all too tragically borne out three days later, when the crowd got out of hand and trampled 400 of its helpless individual members to death.

Calcutta was another manifestation of India's mere bulk. The overgrowth of cities has been a constant accompaniment of the growth of population: the hypertrophy of Calcutta has been exceptionally rapid and severe. In 1941 the population of greater Calcutta was under three million; today it is nearly five million. Its appalling slums are crowded to the rooftops, and at night the pavements are strewn with an overflow of people who have nowhere else to sleep and are forced to share the streets with the miserable roaming cattle. This was impressed upon me on the evening of my first day in the city by a scene I shall never forget. In one of the busiest streets a man and a cow approached a traffic island from opposite angles and composed themselves for the night on either side of the traffic policeman.

The Government of the new, independent India born in 1947 showed a refreshing courage in grasping the formidable nettle of overpopulation. Recognizing that superabundance of people was one of the major obstacles to Indian prosperity and Indian progress, they made the control of population one of the aims of their first Five-Year Plan. The Census Commissioner of India, in his report on the 1951 census, put the problem in quantitative terms. Efforts to keep pace with the growth of population by increasing food production were bound to fail, he said, when the population passed 450 million. If, however, India could "reduce the incidence of improvident maternity to about 5 per cent," an increase of 24 million tons per year in agricultural productivity would be sufficient to feed the population and bring a "visible reduction of human suffering and promotion of human happiness."

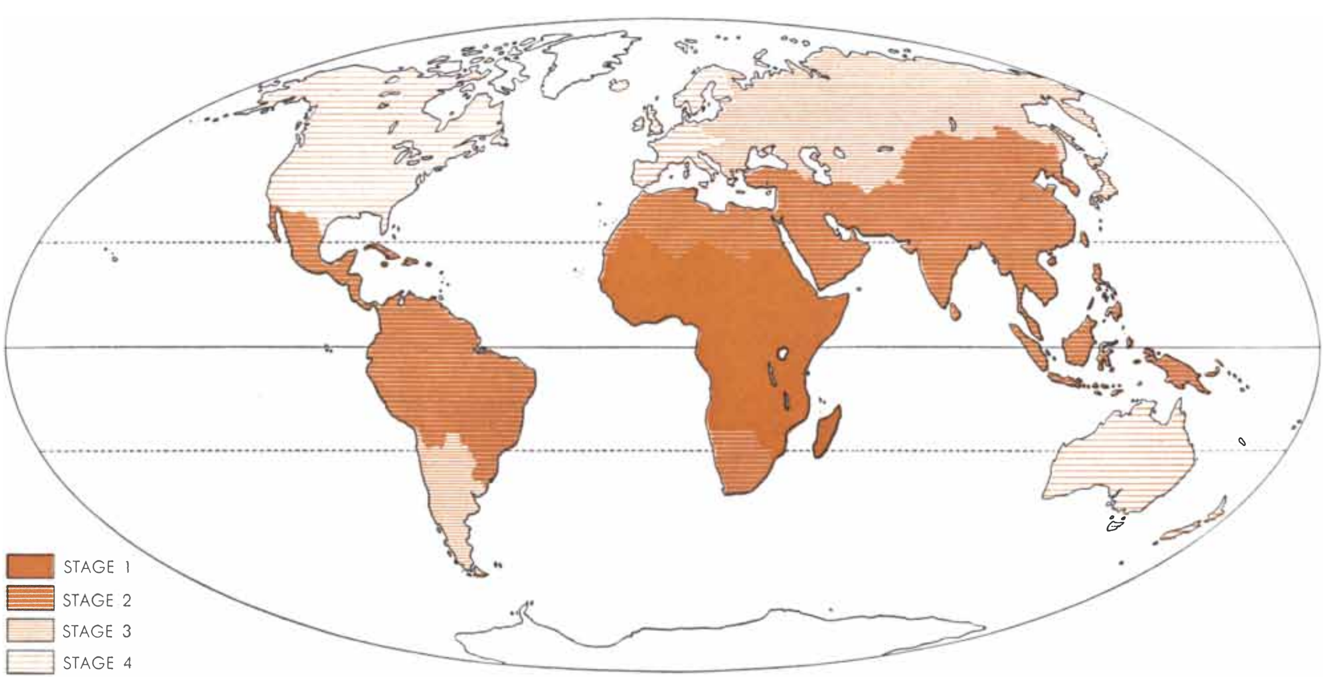
India's Efforts

The Indian Health Ministry has made grants for research on new contraceptives, for certain population studies, for training workers in the field of family planning and maternal and child welfare, for educating public opinion, and for assisting the family-planning ventures of state governments and voluntary organizations.

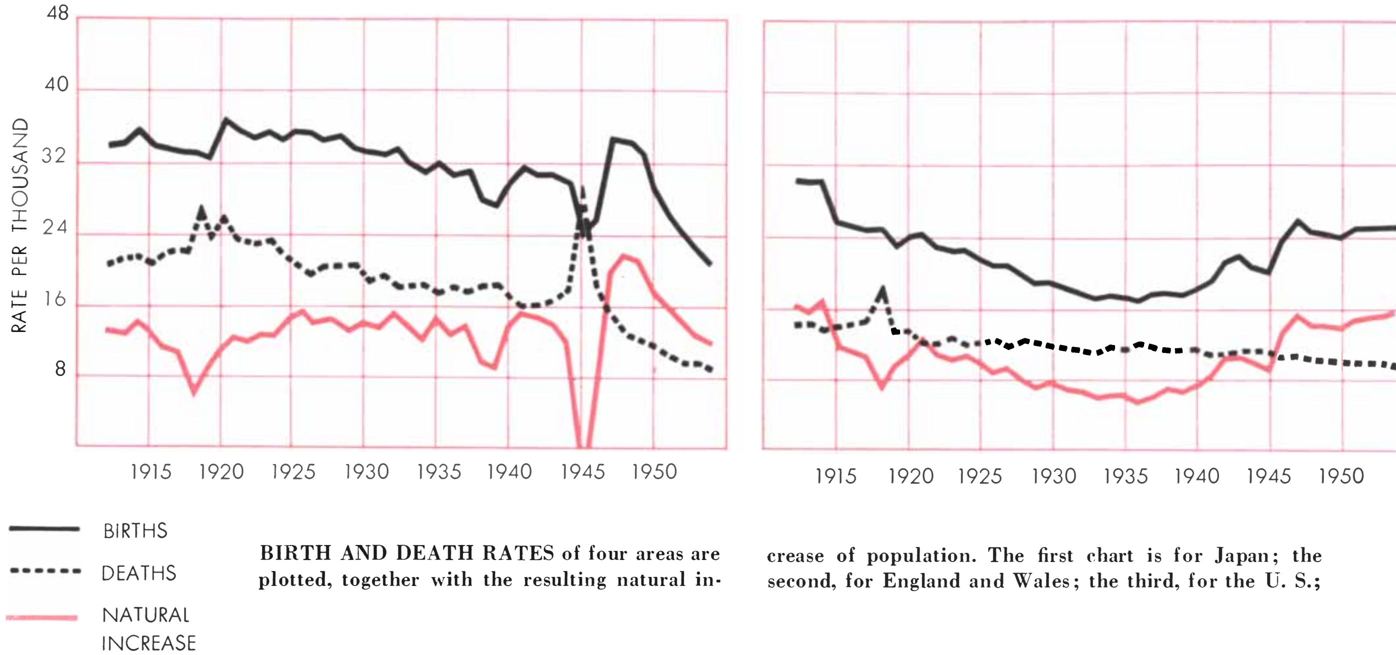
It is heartening that a great country like India should make population control part of its national policy. But it must be confessed that the effects are as yet exceedingly small, and that to an outside observer the execution of the policy seems rather halfhearted.

Let me take an example. The one large-scale experiment initiated by the Government itself has been a pilot study of the so-called rhythm method of birth control, which is notoriously unreliable, owing to the great variation among individual women, and even in the same woman at different times, in the monthly period of infertility. I had the opportunity of visiting the chief center of the experiment in a village near Mysore, and of interviewing the capable and attractive woman in charge, a Negro social scientist from the U. S.

The results of the experiment were interesting. About three quarters of the married women in the village said they would like to learn some method of limiting their families. After their individual cycles were studied each woman was given a kind of rosary, with differently colored beads for "safe days" and "baby days." With this guidance a number of the women managed to avoid pregnancy during the 10 months of the experiment. The social scientist in charge thought that about 20 per cent of Indian village families might learn to



STAGES OF POPULATION CYCLE are also mapped. Stage 1 is characterized by high birth rates and high death rates; Stage 2, by high birth rates and falling death rates; Stage 3, by falling birth and falling death rates; Stage 4, by low birth and low death rates.



BIRTH AND DEATH RATES of four areas are plotted, together with the resulting natural increase of population. The first chart is for Japan; the second, for England and Wales; the third, for the U. S.;

practice the rhythm method successfully. This was a maximum; in any widespread campaign the figure is much more likely to be 15 or 10 per cent. Thus the method would be quite inadequate to control population growth to any significant degree.

Methods used in Western countries are difficult to apply in India, partly because of the cost, partly because of the lack of privacy and hygienic facilities in the vast majority of Indian homes. In addition, there is the persistent influence of Gandhi. As he narrated in his autobiography, Gandhi indulged excessively in sexual pleasure after his marriage. As a result of his disgust at his own indulgence, and his dislike of anything he considered to be scientific materialism, he pronounced against all mechanical or chemical methods of birth control and solemnly recommended abstinence as the cure for India's population problem!

The ideal solution would be the discovery of what laymen (much to the annoyance and distress of the experts) persist in calling "the pill"—a cheap and harmless substance taken by mouth which would temporarily prevent conception, either by preventing ovulation or by rendering the egg unfertilizable. A number of promising substances are being investigated, including some extracts of plants used by primitive peoples. So far nothing safe and reliable has emerged. But our knowledge of reproductive physiology and of biochemistry has been so enormously increased in the last few decades that I would be willing to bet that a solution can be found. A large-scale, concerted program of research is necessary, as it was for the atomic bomb. If we were willing to devote to the problem of controlling human reproduction a tenth of the money and scientific brain-power that we are devoting to the release of atomic energy, I would prophesy that we would have the answer within 10 years, certainly within a generation.

One of the facts that prompted the Indian Government to undertake the task of reducing population increase was the ghastly recurrence of famine in 1952, when a major tragedy was averted only by large-scale importations and gifts of wheat and other foodstuffs from other countries. Famine will continue to recur in India so long as population is not brought down into a reasonable balance with the production of food.

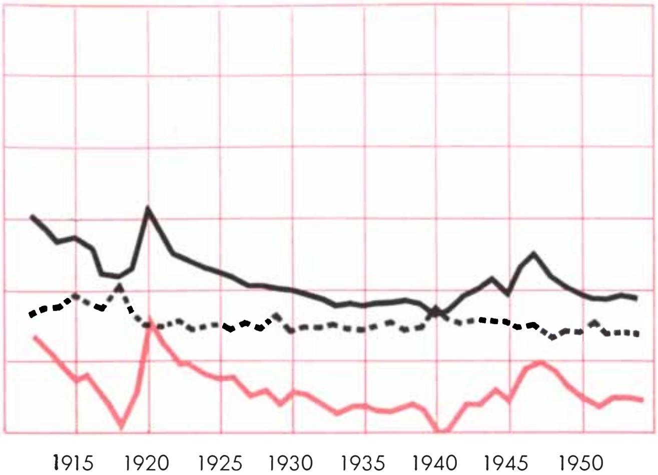
The Government has made heroic efforts to increase food production, and for the first time in modern history India has now a surplus of home-grown food—at the meager-diet level. But this has been made possible by two good seasons of abundant rain; when the climatic cycle brings the bad years around again, as it inevitably will, hunger once more will stalk the land. The long-term prospect is blacker: if population goes on increasing by five millions or more a year, food production cannot possibly continue catching up with the mouths to be fed.

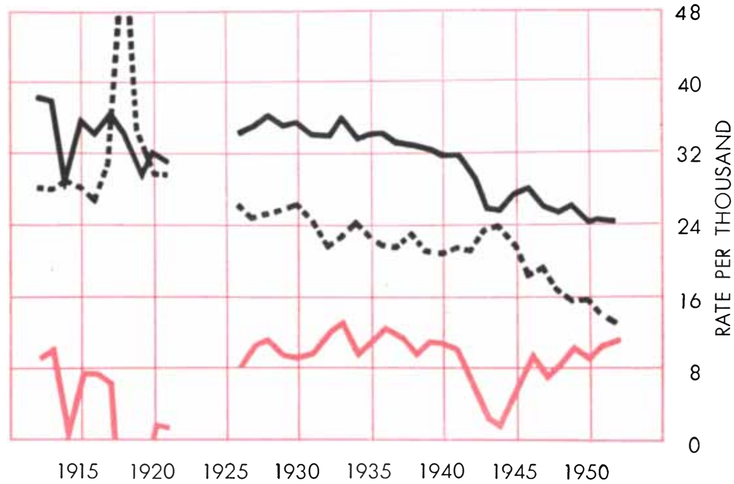
The Government is also devoting more and more attention to industrializing the country, both by small-scale village industries and by large-scale projects. However, while industrialization is highly desirable, it is chimerical to suppose that it alone can cope with India's food and population problem.

Indonesia

Indonesia, another country with an extraordinary population problem, contains the most densely populated large island in the world. Java has more than 50 million people on its 50,000 square miles—a density of population nearly twice that of highly industrialized Britain. Yet Java is almost entirely agricultural. Its cultivable land is very fertile, but there is less than two fifths of an acre per head. And much of the land is devoted to exportable products, so that rice has to be imported to feed the people, even at the insufficient level of about 2,000 calories per day.

Java's already overcrowded population is increasing at a compound interest rate of at least 1.5 per cent per year. A simple answer seems at hand: The excess should be transferred to the large nearby Indonesian islands of Sumatra and Borneo, which are far less thickly populated. But this facile suggestion has proved to be quite impracticable. With considerable difficulty the Indonesian authorities have persuaded some Javanese to move to Sumatra, but many of these have not been able to stand the hardships of pioneering agriculture and have either returned to Java or settled into a depressed urban life on the Sumatra coast. The fact is the material resources and the skills needed to convert the dense equatorial forest of Sumatra





the fourth, for India. The peak in the death rate of all these areas between 1915 and 1920 is due to the influenza pandemic of 1918-1919. The peak in the Japanese death rate for 1945 is largely due to war casualties. The gap in the curves for India is due to lack of data.

and Borneo to agricultural production are not available. This is not to say that settlement should not be attempted. But resettlement of Java's population on the largest possible scale, plus other economic and political development, could not possibly cope with more than a part of Java's formidable annual surplus of people. Birth control also is necessary. Unfortunately there is no sign yet that the Indonesian Government recognizes this necessity.

Bali, whose population density (over 500 per square mile) is about half that of Java, grows just about enough rice to feed itself. However, if its population continues to grow at the present high rate it will seriously outstrip food production in two or at most three generations. Bali provides an extreme illustration of the erosion of a culture by world population pressure. The Balinese have a rich and vital cultural tradition, in which beauty is woven into everyday living. Every aspect of life is marked by some celebration or embellished with some form of decoration. Every Balinese participates in some form of creative activity—music, dance, drama, carving, painting or decoration. What is more, the tradition is not rigid, and the culture is a living and growing one, in which local and individual initiative are constantly introducing novelty and fresh variety. But the Balinese are afflicted with many preventable diseases; they are largely illiterate (though far from uncultured); their religion is now being undermined by the Christian missionaries who have at last been allowed to work in Bali; growing economic pressure forces them to take advantage of the flood of cheap mass-produced goods from Western technology; their mounting population demands some adaptation to modern industrial life if living standards are to be raised or even maintained, and this in turn is imposing a Westernized system of compulsory education.

Most foreign residents prophesy that Bali's unique and vital culture is doomed, and will wither and die within 10 or 15 years. This may be overgloomy, but certainly it is in grave danger. We can only hope that the Indonesian Government will realize the value of this rich product of the centuries, and that UNESCO will justify the C in its name—C for Culture—and do all in its power to help. No one wants to keep the Balinese in a state of ill health and ignorance. Yet instead of being pushed by the well-meaning but ill-considered efforts of overzealous missionaries and "scientific" experts to believe that their traditional culture is a symbol of backwardness, they could be encouraged to retain faith in the essential validity of their indigenous arts and ceremonials, and helped in the task of adapting them to modern standards. A traditional culture, like a wild species of animal or plant, is a living thing. If it is destroyed the world is the poorer.

Thailand and Fiji

The situation of Siam, or Thailand as it is now officially called, is in some ways not dissimilar to that of Bali. It is in the fortunate position of producing enough rice not only to feed its own people but also to export a considerable amount to less favored countries. Its people are well fed and look cheerful. Thailand is proud of its past, and especially of the fact that it alone of Southeast Asian countries has never lost its independence. There is a traditional culture in which the bulk of the people are content to find fulfillment, though there is not so much active participation or artistic creation as in Bali. At the same time, Thailand is crowded with organizations and agencies, international and national, which are giving advice and assistance on every possible subject: health, education, agriculture, democracy, scientific development, administration, industry, fish ponds and rural community life. As a result the traditional Siamese culture is being crushed or undercut.

Unless Thailand's birth rate falls along with the death rate, she will lose her proud distinction among Asian countries, and will become seriously overpopulated well before the end of the century. Thailand needs better coordination of her departments of government with the motley collection of foreign agencies, and an over-all plan which would take account of population and traditional culture as well as food production and industry, science and education.

Fiji is another island, with another problem. Its population of about a third of a million is made up of two separate populations, which at present are about equal in number—the indigenous Fijians and the immigrants from India (together with a handful of Europeans, Chinese and others).

The history of the two populations is instructive. The native Fijian population

CHILD BRIDE and her mother were photographed by the author near Mysore in India. It has been suggested that curtailing child marriage would help curb the population increase.

numbered nearly 200,000 in 1850, had fallen to 150,000 when the islands were taken over by the British in 1874, and was steadily reduced by a succession of epidemics to a point well under 100,000 before health measures introduced by an alarmed administration reversed the decline. It is now around 140,000. Immigration from India started in 1879 and has continued to the present day. The Indian population outstripped the Fijian during World War II and has now passed 150,000. Since its rate of increase is well above that of the Fijians, Indians will in the space of two or three generations constitute a large majority unless present trends change.

The two groups are very different in physique, cultural background, interests and work habits. The Fijians have the finest physique I have ever seen: they make good soldiers and wonderful athletes. But their athletic and warlike propensities have induced no great keenness for Western education, and a definite dislike of regular agricultural work. Indians largely man Fiji's sugar plantation economy. They make excellent laborers and small farmers and traders, and have a notable thirst for education. They have even started secondary schools on their own initiative and at their own expense.

There is little intermarriage between the two groups, and indeed little liking. The Indians tend to regard the Fijians as barbaric, while the Fijians (who still take a sneaking pride in their warlike and cannibal past) find the Indians effeminate and affect to despise their laborious way of life. However, there are now signs of a rapprochement, and some of the younger Fijians are realizing that they must change their attitude toward work and education if the Fijian community is not to lapse into a sort of living fossil, cushioned by the protective measures of the Colonial Government. Once this new attitude is realized in practice, and the Fijians accept Western standards more wholeheartedly, their death rate is bound to fall and their numbers to jump. Since the Indian rate of increase shows no signs of falling, a demographic crisis looms ahead. Fiji will become overpopulated within the lifetime of its younger inhabitants, unless the Fijians and Indians alike are introduced to the necessity and desirability of family limitation. Unfortunately birth control is still taboo, or at least not publicly acceptable, in the British Colonial Office (and indeed in the governments of all other colonial powers). I can only hope that too much economic distress and social misery will not be required to force the action that present intelligent foresight could undertake—and could now undertake with much less difficulty than when the cohorts of the yet unborn have swelled the population to disastrous proportions.

Australia

Australia is a storm center of demographic controversy. She is a continent of close on three million square miles with only nine million human inhabitants. Yet she is committed to a "white Australia" policy, and admits no Asians or Africans as immigrants, though she is on Asia's back doorstep. The three great swarming countries of Asia—India, China and Japan—have for decades been casting longing eyes on Australian space as a possible outlet for their surplus people: if the Axis powers had won the war, the Japanese undoubtedly would have established settlements in Australia on a large scale.

However, Australia's open spaces are, from the point of view of human occupation, largely a mirage. For an indefinite time its uninhabited areas will remain blanks on the world's map. Three quarters of Australia is desert or semidesert. At the present time only 2.5 per cent of Australia's land is cultivated. It is true that big irrigation schemes are being planned, and that the discovery that much poor land could be enriched by adding trace elements is heartening the farmers and wine growers and herders. But heavy additions of fertilizers would also be needed, and these, like irrigation schemes, are expensive.

Never is a big word, but it looks as if much of the land can never be brought into cultivation. I was driven down from Darwin to Alice Springs—a thousand miles of increasingly sparse bush and increasingly stony and barren soil, miserable and for the most part intractable to human effort. The best estimates put 7.5 per cent as the maximum area of Australia's surface which can be brought into cultivation, and to achieve even this will demand great effort and great expenditures of capital.

Australia is underpopulated in the double sense that it could support a larger population and that a larger population would benefit its economy. How much larger is a question. Some say 50 million people, but this seems an overoptimistic estimate. A total of 25 or at most 30 millions seems more reasonable. And this would absorb less than one year's increase of Asia's population, less than five years of that of India alone. Furthermore, Australia already is hard put to it to keep up living standards in the face of its present rate of population growth, which is one of the highest in the world (about 2.5 per cent per annum), thanks to its policy of encouraging and assisting immigration from Europe. Thus the idea of Australia becoming an outlet for the spill-over of Asia is chimerical. The highest rate of human absorption possible without jeopardizing economic health could not take care of more than a small fraction of Asia's annual increase.

The white Australian policy remains as an affront to Asian sentiment. But this too has, in my opinion, strong arguments in its favor. Certainly it cannot and should not be justified on grounds of racial superiority or inferiority: there is no such thing. But it can be justified on cultural grounds. Cultural differences can create grave difficulties in national

OPEN-AIR BARBERSHOP beside a cow in Benares illustrates the conditions of sanitation which have traditionally kept the Indian death rate higher than that of Western countries.

ROW OF BEGGARS in Benares characterizes the narrow margin of subsistence in the large cities of India. All the photographs on pages 72 through 74 were made by the author.

FISH PONDS were photographed from the air along the coast of Java. In these shallow bodies of water the Javanese breed fish as part of the effort to solve their food problem.

RICE PADDIES on terraced hillsides in Bali indicate intensive use of the land. The Balinese grow all their own food, but within a relatively short time they may have to import it.

FISH TRAP is built by a fisherman in a Philippine stream. In their intensive fisheries the Filipinos also wade neck-deep to catch shrimp, and dip fish from water with ingenious nets.

development. They often do so when cultural and racial differences are combined. A large minority group which clings to its own standards and its own cultural and racial distinctiveness inevitably stands in the way of national unity and creates all sorts of frictions. And if the immigrant group multiplies faster than the rest of the population, the problem is aggravated, as we have seen in Fiji.

It should be put on record that there is little color prejudice in Australia. For its aborigines—the only nonwhite permanent inhabitants of the continent—the watchword now is assimilation: they are gradually to be incorporated into the country's social and economic life. Australia is also admitting a number of Asians as students or trainees, and giving them a very friendly welcome. What Australia seeks to guard against is the creation of permanent racial-cultural minorities.

Resources

Such are some of the population problems of individual countries as I saw them in my tour of Asia and the Far East. The obverse of the population problem is the problem of resources, and I must say a word about the alarming differentials in consumption between different regions and nations. Even in food these are serious enough. The average daily diet in India (1,590 calories) is less than half that in countries such as the U. S. or Ireland. And between the more privileged classes of favored countries and the poorer ones of the underdeveloped countries the difference of course is much greater—nearly fourfold instead of twofold. When we come to other resources, the contrasts are still more startling. In the field of energy, the U. S. per capita consumption is double that of Britain and more than 20 times that of India. The U. S. consumes 80 times more iron per capita than India and nearly two and one-half times more newsprint per capita than Britain. It uses about two thirds of all the world's production of oil.

As facts like these seep into the world's consciousness, they are bound to affect the world's conscience. Such inequalities appear intolerable. The privileged nations are beginning to experience a sense of shame. This guilty feeling finds a partial outlet in the various international schemes for technical and economic assistance to underdeveloped countries. But these schemes are not nearly bold or big enough. We need a world development plan on a scale at

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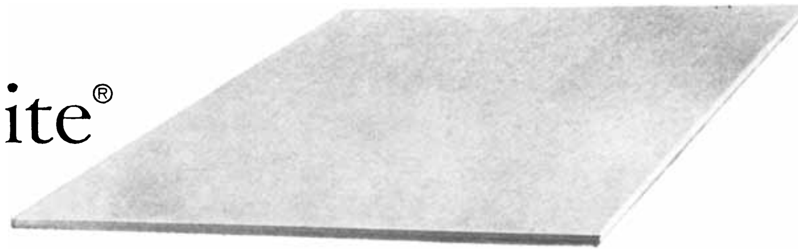

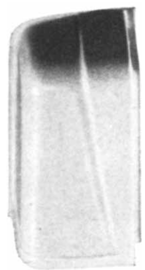

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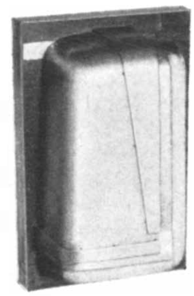

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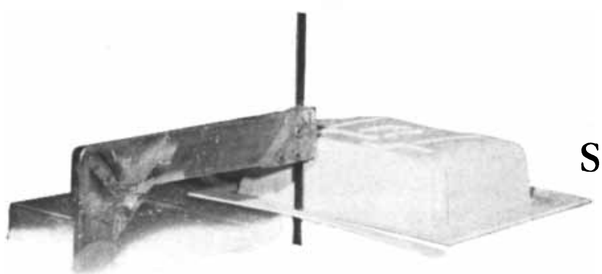

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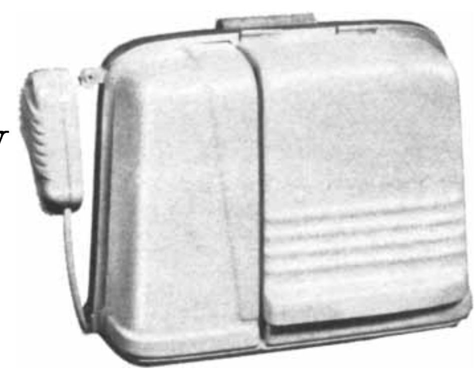

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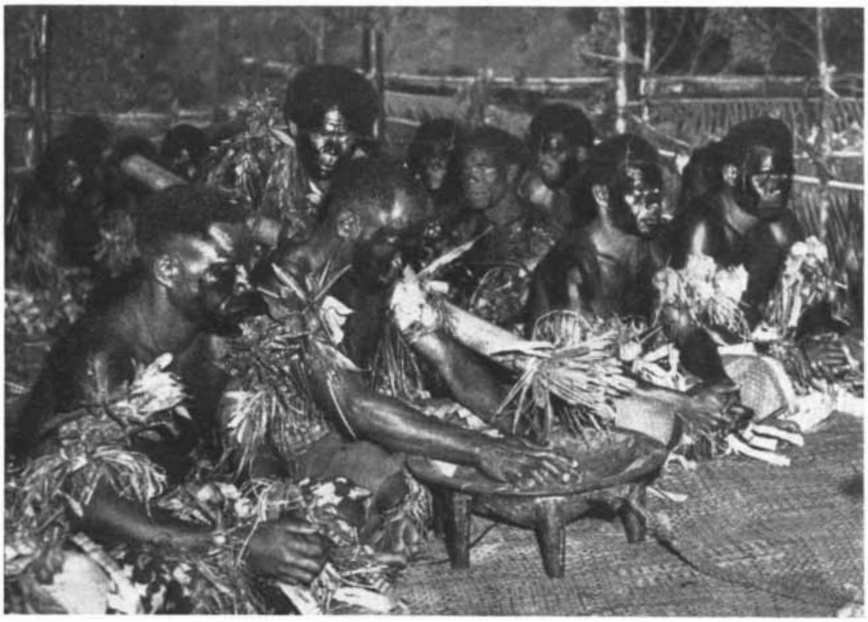
least 10 times as big as all existing schemes put together—a joint enterprise in which all nations would feel they were participating and working toward a common goal. To achieve even the roughest of justice for all peoples, the favored nations of the world will have not merely to cough up a fraction of their surpluses but voluntarily to sacrifice some of their high standard of living. For their part the underdeveloped countries, to qualify for membership in the international development club, must be willing not only to pledge themselves to hard and intelligent work but also to restrict their population growth.

As I have emphasized, the crux of the problem lies in establishing a satisfactory balance between the world's resources and the population which uses the resources. The Political and Economic Planning report to which I have referred surveys in some detail the prospects of the world's main resources for the next 25 years. It concludes that so far as energy, minerals and other inorganic raw materials are concerned, the total world requirements probably can be met during that period, and for energy the prospect continues reasonably bright up to the end of the 20th century. But when it comes to food, a world deficiency "of appalling magnitude" already exists, and "supplying the necessary foodstuffs to feed the expected newcomers and also to bring about substantial and lasting improvement in the position of the many millions now underfed is likely to prove exceedingly difficult and increasingly precarious."



KAVA CEREMONY is conducted on the island of Fiji. The athletic and warlike Fijians are slow to accept education and agriculture. Their numbers have decreased since 1850.

INDIAN HIGH SCHOOL on Fiji was visited by the author (*center*). Immigration to Fiji from India began in 1879. Today the Indian population on the island outnumbers the Fijian.

This forecast, it must be emphasized, applies to global consumption; when we take the position of individual countries into account, the situation appears even more serious. The trend is toward a widening of the already grotesque differences in consumption between the well-nourished and the undernourished regions of the world. For one thing, a rise in living standards in food-exporting countries is reducing the amount of food they have available for export; for example, Argentina is exporting less meat because its people are consuming more of its production.

Everything points to one conclusion. While every effort must be made to increase food production, to facilitate distribution, to conserve all conservable resources and to shame the "have" nations into a fairer sharing of the good things of the world with the "have-nots," this alone cannot prevent disaster. Birth control also is necessary, on a world scale and as soon as possible.

Though I may seem to have painted the picture in gloomy colors, I would like to end on a key of hope. Just as the portentous threat of atomic warfare has brought humanity to its senses and seems likely to lead to the abandonment of all-out war as an instrument of national policy, so I would predict that the threat of overpopulation will prompt a reconsideration of values and lead eventually to a new value system for human living. But time presses. This year will add more than 34 million people to humanity's total, and certainly for two or three decades to come each successive year will add more. If nothing is done soon, world overpopulation will be a fact well before the end of the century, bringing with it an explosive cargo of misery and selfish struggle, frustration and increasingly desperate problems.

It has taken just one decade from Hiroshima for the world to face up resolutely to the implications of atomic war. Can we hope that it will take no more than a decade from the 1954 World Population Conference in Rome for the world to face up equally resolutely to the implications of world overpopulation?

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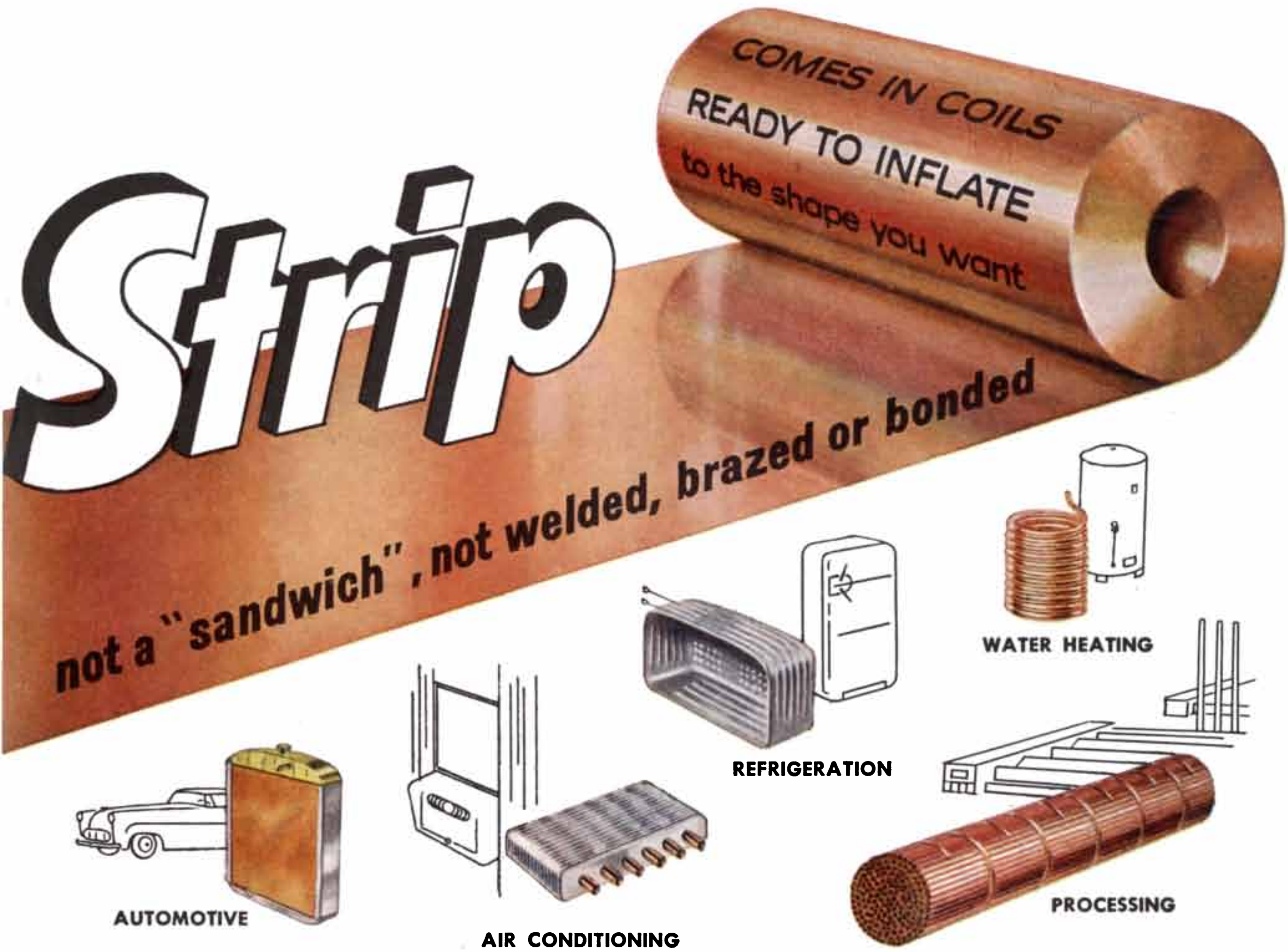

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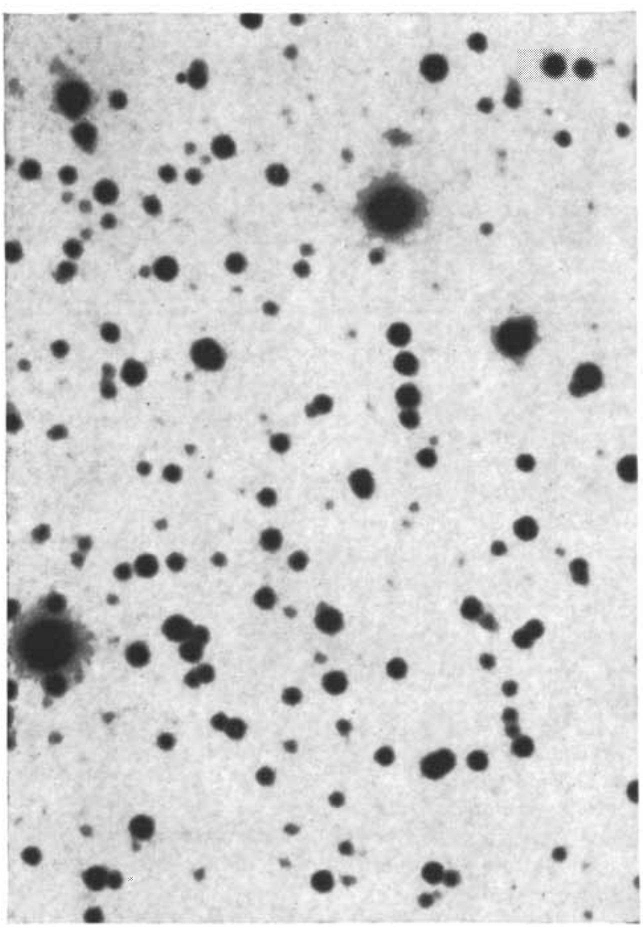
Electronic Photography of Stars

The power of present telescopes may soon be increased by devices that convert the light of faint stars and galaxies into electrons, which may then be accelerated and focused on a photographic plate

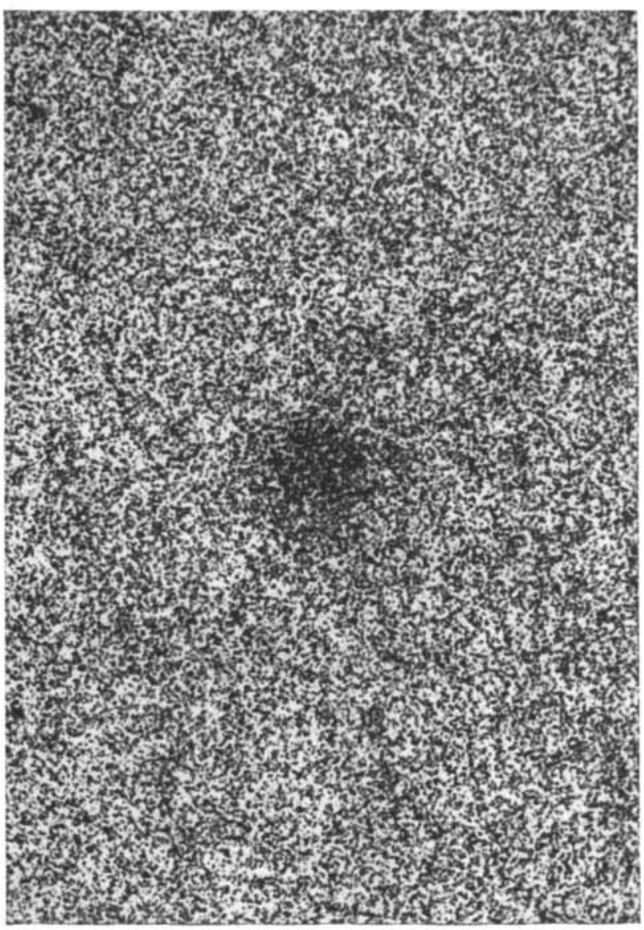
by William A. Baum

In the 20th century we have vastly widened our view of the universe by building bigger and bigger telescopes looking farther and farther into space. Each expansion of the view has produced discoveries and new questions calling for still bigger telescopes. But with the great 200-inch Hale telescope on Palomar Mountain we have reached certain practical difficulties which stand in the way of further progress. The cost of building a substantially larger telescope would be very great. And we are unable to take full advantage of the 200-inch instrument's capabilities because of limitations imposed on our seeing by the earth's atmosphere.

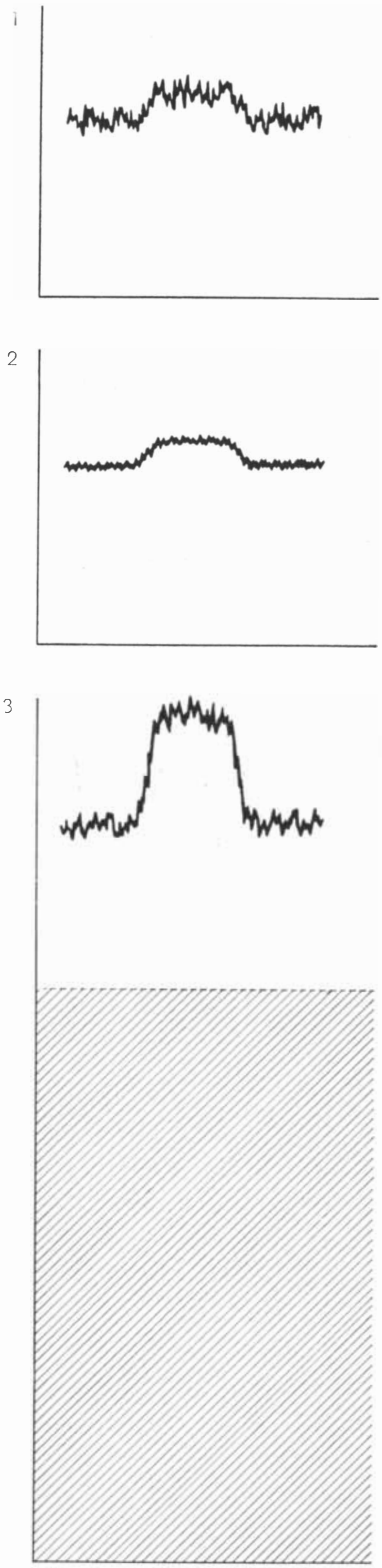
Astronomers have therefore taken to other stratagems. Radio astronomy, of course, is one. Improvements in photographic plates and in light-measuring devices constitute another. Within the last couple of years there has been rapid progress in an exciting development



STAR IMAGES appear in a positive print of a photographic plate exposed at the prime focus of the 200-inch telescope. Even though the plate was made during good seeing, the images are not sharp. The print enlarges a section of the plate seven millimeters wide.



ENLARGED IMAGE of a faint star (magnitude 20.5) is outlined by the individual grains of a fast photographic plate exposed for five minutes at the prime focus of the 200-inch telescope. The print enlarges a section of the plate that is only .7 millimeters wide.



INTENSITY PROFILE of the image of a very faint star on an unaided photographic plate is presented by a simulated microphotometer record (1). This image could be intensified by converting light quanta into electrons and using the electrons to expose a fine-grained plate (2). It could also be intensified (3), by amplifying the number of electrons and subtracting the signal due to the background radiation (*shaded area*).

which promises to cut through the telescope dilemma in truly spectacular fashion. Essentially the idea is to multiply the efficiency of the optical telescope by hitching on an electronic "camera"—applying principles used in television. Work on this idea is going forward so actively that one might venture to say that a major revolution in telescopy is in the making, just as the electron microscope has revolutionized microscopy by giving us a deeper view into the small universe of molecules and atoms.

Let us look first at the causes of the astronomers' difficulties. The frustration of telescopes stems mainly from two properties of our atmosphere: (1) turbulence in the air and (2) the phenomenon known as night sky glow.

Turbulent movements of the air layers in our atmosphere have the effect of making the stars twinkle or dance, so that even on the stillest and clearest nights it is impossible to make anywhere nearly as sharp a photograph of a star as the 200-inch telescope is optically capable of producing. This "seeing" factor blurs the star image on the photographic plate; the image appears not as a point but as a smear which at best is spread out to a diameter of about one tenth of a millimeter.

The night sky glow is due to chemical processes in the earth's upper atmosphere which produce phosphorescence [see "Aurora and Airglow," by C. T. Elvey and Franklin E. Roach; Scientific American, September, 1955]. On an average moonless night the night glow sheds about twice as much light on the surface of the earth as do all the stars combined. Obviously as we look at fainter and fainter stars it becomes increasingly difficult to distinguish their light from the night sky glow. On a photographic plate the image of a very faint star is a tiny gray smudge on a slightly lighter gray background. When we get to faint stars of the 24th magnitude, the starlight is so little brighter than the background that the stars are only barely detectable, if at all. Stars fainter than this are completely drowned in the glow.

As a radio engineer would say, our trouble is a low signal-to-noise ratio. The problem facing us in photographing faint stars is to strengthen the signal and weaken the noise: that is, to find some way to improve the contrast between the star and the background. What this involves in photographic terms can be made clear by a close study of the photograph of a faint star.

Let us look through the microscope at a small section of a lightly exposed plate

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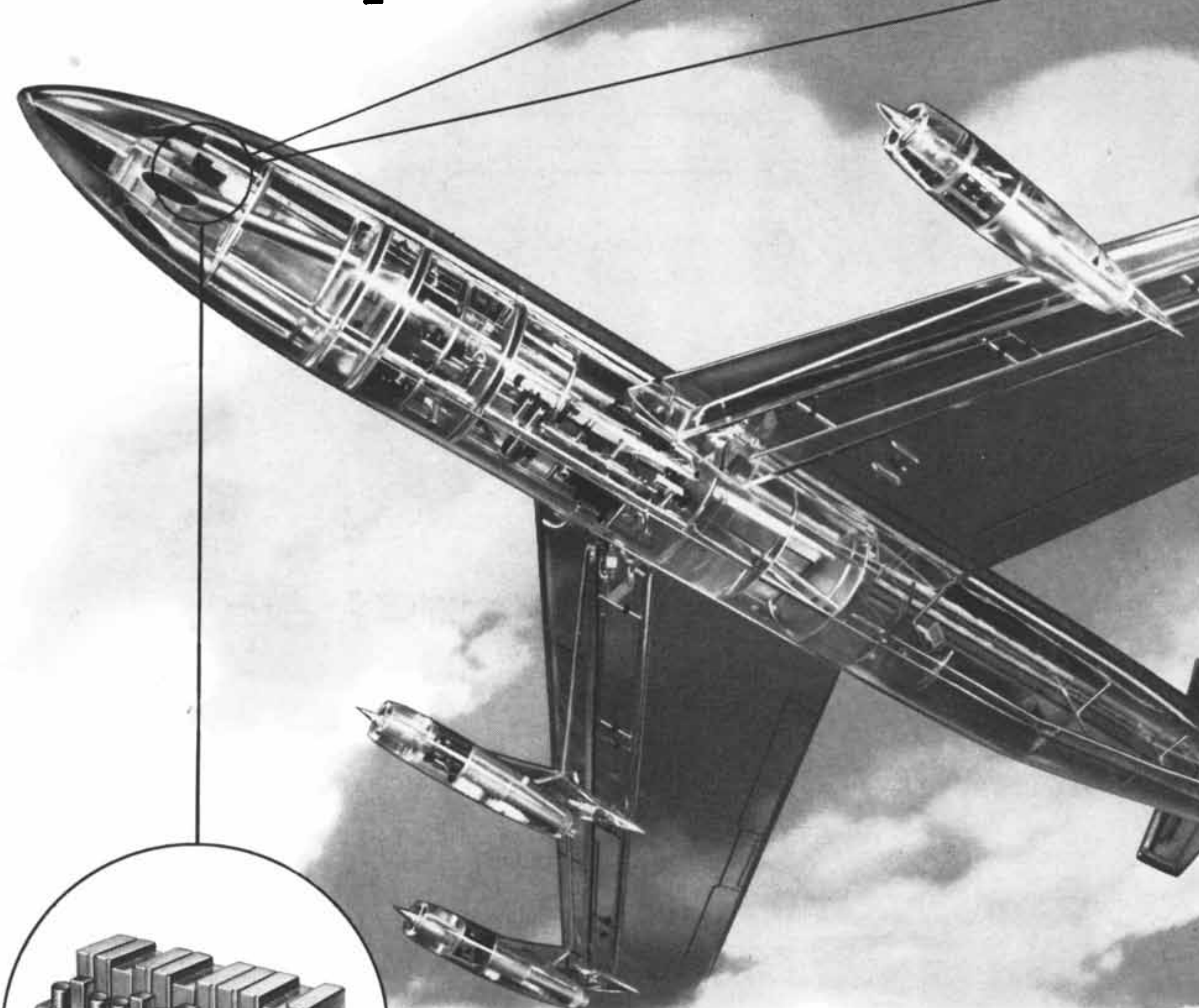

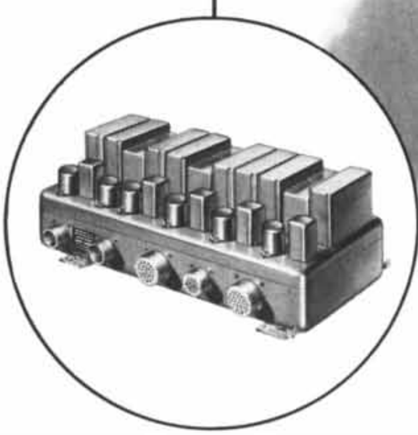

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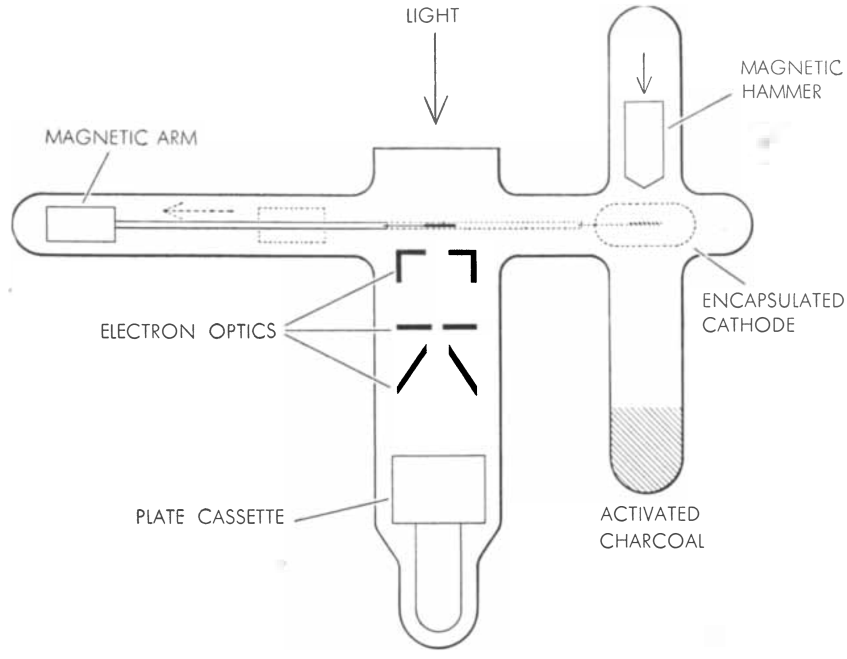

IMAGE CONVERTER designed by André Lallemand of the Paris Observatory has its photographic plate sealed into an evacuated glass tube. Just before the exposure is made, a capsule protecting the photocathode is broken with a hammer moved by a magnet outside the tube. The cathode is then pulled into position by a magnet. When light falls on the photocathode, it emits electrons which are accelerated and focused by the electron optics.

with the image of a single faint star [*see photograph at the right on page 81*]. The plate as a whole is grayed by photographic grains which have been blackened by the night sky glow; the star image is a little darker because more grains have been blackened there. Now if we divide the plate into unit areas, each the size of the smeared star image (about one tenth of a millimeter across), and count the blackened grains in each area, we will establish two facts. First, of course, the star area has more black grains than any of the others. But we also discover that the unit areas in the rest of the plate have different counts: some have more black grains than others. This means that if a faint star is to be distinguishable from the background, it is not enough that the star area on the plate be darker than the average unit area: its dark-grain count must exceed the background fluctuations. In other words, it must be darker than the darkest unit area in the background.

We can improve the contrast between the star image and the background by exposing the plate longer. Now there are more black grains in each unit area, and the percentage of fluctuation is therefore smaller. The relative range of fluctuation decreases in proportion to the square root of the average number of grains per unit area in the background. Consequently if we quadruple the exposure time, the plate will show stars twice as faint. However, we soon reach a limit in this improvement of contrast: the limit comes when the darkened grains overlap, so that further increase in the number of black grains in the emulsion no longer reduces the relative fluctuation of the background surface.

This is the problem and the basic limitation of the 200-inch telescope. Using a fast photographic plate, it can detect fainter and fainter stars as the exposure time is increased—up to 30 minutes. At this point the photograph shows about as much as it's going to, and further exposure is likely to result in a loss rather than a gain. Actual photographs agree with the theoretical limit: they show that the 200-inch cannot detect stars or nebulae fainter than the 24th magnitude.

Now all this suggests there are two ways we might attack the problem of photographing fainter and more distant stars with present telescopes (not only the 200-inch but also smaller telescopes). First, we might use smaller grains, thus obtaining a greater number of developed grains per unit area before we reach the saturation point of overlapping. Second, we might seek to improve the contrast between the starlight and

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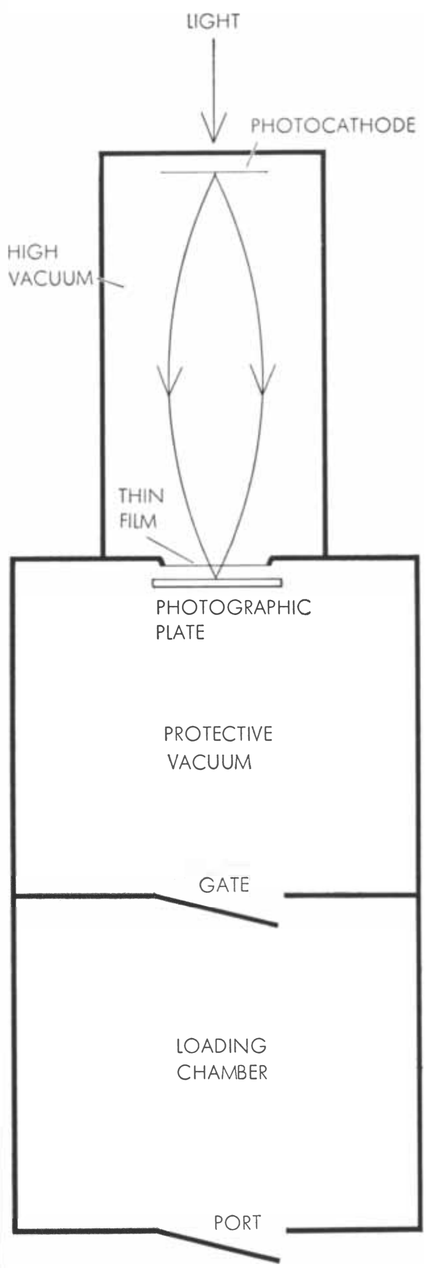
A photographic plate with ultrafine grains is inherently very slow. It would require a prohibitively long exposure to photograph faint stars. Hence the essence of the problem is to speed up the pace of the exposure. We need a method of intensifying the exposure, or, to put it another way, of improving the efficiency with which quanta of light (photons) are translated into blackened grains on a plate. Electronics offers an answer because the conversion of light into photoelectrons is far more efficient than its conversion into developable photographic grains. When light strikes a photographic emulsion, one developable grain is produced for every thousand photons of incident light. When it strikes a light-sensitive metal that ejects electrons, one electron is ejected for every 10 photons of light. Thus the photosensitive metal surface, known as a photocathode, is 100 times more efficient than a photographic emulsion in reacting to photons. If we can make full use of this efficiency, translating each electron into a blackened grain on a photographic plate, we can speed up telescopic photography a hundredfold.



THIN-FILM CONVERTER is depicted in this schematic diagram. Light causes the photocathode to emit electrons (*curved arrows*), which are electrostatically focused so that they pass through the thin film and fall upon the photographic plate. The thin film protects the photocathode against contamination by the gases exuded by the plate.

André Lallemand of the Paris Observatory produced a pioneer device along this line. It brings together a photocathode and a photographic plate in a single vacuum tube [*see drawing on page 84*]. Since a photographic plate gives off gases which "poison" the photocathode (make it insensitive to light), the latter is enclosed in a glass capsule until the last possible moment. When the exposure is to be made, a magnetically actuated hammer breaks the capsule and the naked photocathode is pulled, also by magnetic means, in front of the exposure window. As incoming light from the star knocks electrons out of the cathode, they are focused into a beam and accelerated by electric fields controlled by three pairs of electrodes in the tube. The beam strikes the photographic plate and there records the star's image. Lallemand can readily obtain one or more developable grains for each electron, and therefore his tube speeds up exposure about 100 times. Attached to a telescope at the focus, the tube has produced some successful pictures of faint stars.

But the exposure of the cathode to gases from the photographic emulsion remains troublesome in this tube. The next step, therefore, is to put the cathode and the photographic plate in separate chambers. Now we must find a way to transmit electrons from one chamber to the other without permitting gases to pass. The answer that was devised is a window made of an extremely thin film—no more than a few millionths of an inch thick. Accelerated to a suf-

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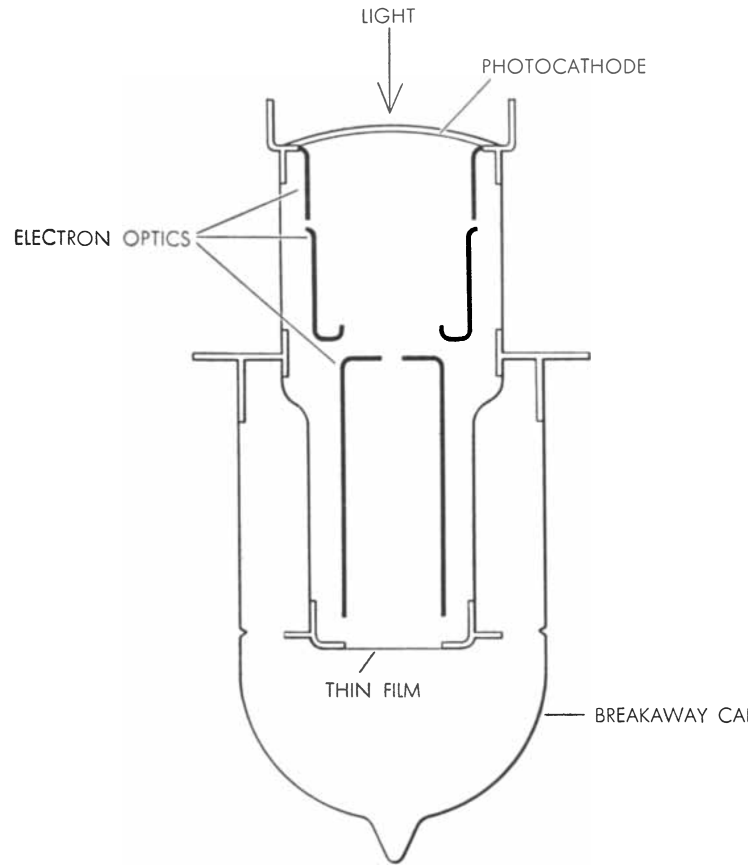


EXPERIMENTAL THIN-FILM CONVERTER has this design. During the shipment and storage of the tube, the thin film is protected by a vacuum in the glass envelope at the bottom. When the bottom of the tube is inserted in a vacuum plate-changer of the sort diagrammed on page 86, the flange at left and right above the center makes a seal against the outside of the vacuum-chamber wall. The cap is then broken off within the chamber.

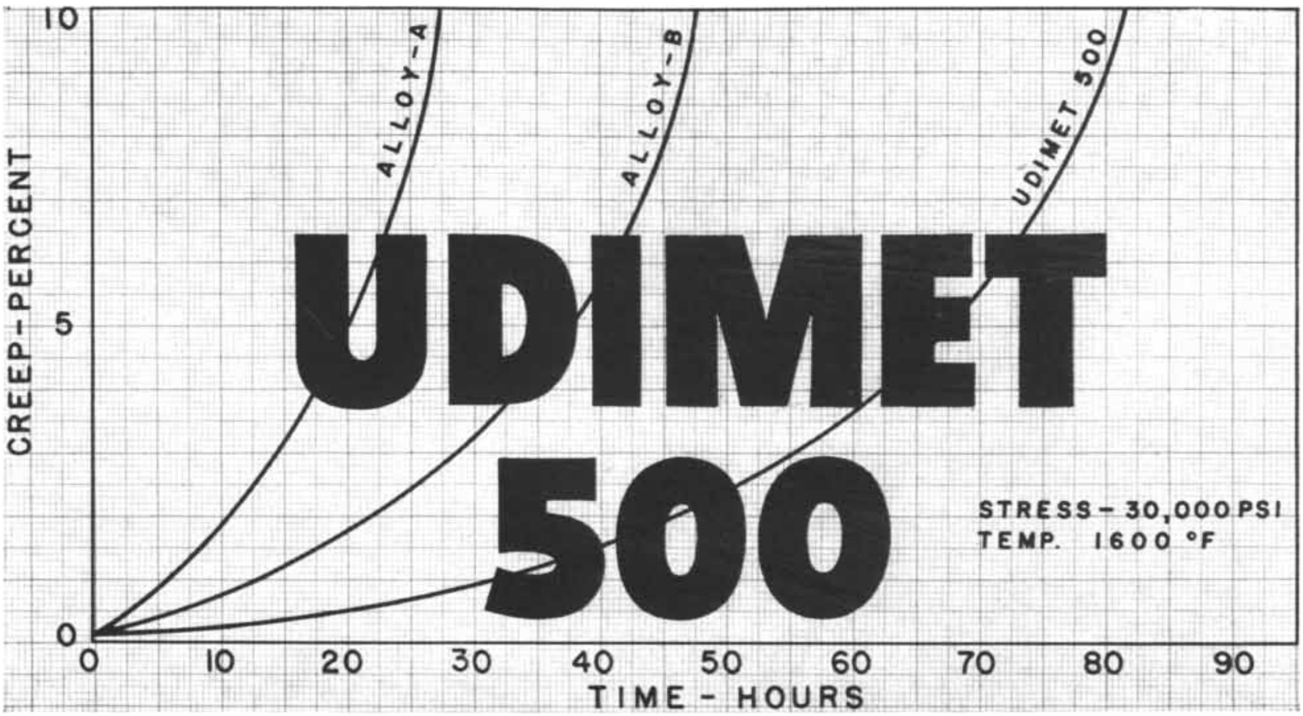
ficiently high velocity, electrons will pass right through this window with very little scattering. Since the chamber containing the cathode is a high vacuum, the photographic chamber also must be at least partly evacuated, in order to avoid rupturing the thin film. The photographic plates are loaded in a third chamber, which is then closed and partly evacuated before the plates are transferred into the exposure chamber. The general features of this system are shown in the diagram on page 86.

W. A. Hiltner and J. Burns of the Yerkes Observatory were the first to experiment with the thin-film system. They have succeeded in keeping the cathode in good condition for several weeks and in achieving a 50-fold increase in photographic speed.

A group with which the author of this article is associated is now working on the development of a practical design for a thin-film image tube which can be used by any astronomer. Our work is sponsored by the Carnegie Institution of Washington, and the group includes J. S. Hall and S. L. Sharpless of the U. S. Naval Observatory and L. Marton and E. S. Dayhoff of the National Bureau of Standards.

The version pictured here [*see diagram above*] is a pilot model of a simple tube about five inches long which can be plugged into a separate vacuum apparatus containing the photographic plates. The tube consists of a photocathode, electrodes for focusing and accelerating the electrons, and a thin film. Over the end of the tube is an evacuated glass cap. When the tube is plugged into the photographic chamber, a mechanism breaks off the glass cap, and the photographic plates can be moved up close to the thin-film window.

Through the cooperation of the Radio Corporation of America experiments are also being carried out with a tube which will not require the plate chamber to be evacuated. In this case rupture of the thin film will be avoided by mak-



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At the research laboratories of the Westinghouse Electric Corporation, E. J. Sternglass and M. M. Wachtel are developing another tube which will not need vacuum apparatus. Their system has no thin window but contains a series of thin films which multiply the number of electrons in the beam.

So much for the fine-grain route toward improving telescopes. The field is very active and further developments are unpredictable. Let us now look at the other attack—erasure of the unwanted background light.

A number of ingenious systems have been proposed, some of them using features already employed in commercial television. The basis of these schemes is the temporary storage of the picture on a nonconducting surface in the form of static electric charges, so that the picture can be "retouched," so to speak, to mute the background. The electric charges representing the image and background are deposited on the insulating surface by the electrons from the photocathode. The contrast between the image and background may then be increased by electronic means. A scanning beam will read off the picture, as in television, and it will then be transmitted to a screen and photographed.

PILOT MODEL of the thin-film converter with a breakaway glass cap diagrammed on page 88 is shown in photograph. The tube was made by the Farnsworth Electronic Company.

No such system has yet been applied successfully to the photography of faint stars, but there have been encouraging developments by G. A. Morton and colleagues at the R.C.A. Laboratories in Princeton and by J. D. McGee at the University of London. A system with exciting possibilities has been built by R. E. Sturm, formerly of the Johns Hopkins Hospital, now with Bendix Aviation Corporation. He modified a television camera and receiver hookup so that the brightness of the original image is multiplied as much as 50,000 times in the final picture. The circuit was developed originally to amplify faint X-ray pictures and is in use for that purpose at the Johns Hopkins Hospital. Bendix is now manufacturing Sturm's device under the trade name Lumican.

Sturm has begun to apply his system to the old business of planet photography. The planets are thousands of times brighter than the night sky glow, but atmospheric turbulence plays hob with the seeing of their details, such as the Martian "canals." With Sturm's light amplifier he hopes to make fraction-of-a-second snapshots of the planets, "freezing" the jumpy image. In tests at the Lowell Observatory the equipment has already made possible "the best view of Mars we have ever had," according to Director Albert G. Wilson.

Altogether we have good reason to hope that "seeing" will soon improve on all fronts in astronomy. According to theoretical calculations, if an ideally efficient electronic image tube were combined with the 200-inch telescope at Palomar, it could see as far into space as an unaided telescope with a 2,000-inch reflector! When we recall the historic successive accomplishments of the 40-inch, 60-inch, 100-inch and 200-inch instruments, and when we stop to realize how much effort was expended in making each of them a working reality, we can appreciate the enormous potential importance of exploiting image tubes to the limit of our technical ability.


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Last October Niels Bohr celebrated his 70th birthday. Physicists all over the world observed the event, some of them by contributing satirical articles on physics

Few scientists alive today are held in greater affection by their colleagues all over the world than the great pioneer of atomic physics Niels Bohr. His name (including his incognito during his World War II visit to the U. S.—"Mr. Brown") is surrounded by legend, and his birthdays are celebrated with appropriate flights of fancy by his friends. On each of his last three decennial birthdays their tribute has taken the form of literary cheer suitable to the occasion. Volume III of these collections of papers appeared on Bohr's 70th birthday, October 7, 1955. One item was a treatise by George Gamow (unfortunately too long to republish here) on the adventures of one Stan Situs, who voyaged to a remote region on the Amazon where he crossed a "vortex point" which reversed everything, as a Moebius strip does, so that his heart was on his right side and he was no longer able to digest proteins made of dextrorotary amino acids.

With grateful acknowledgment to the authors of the papers in question, Scientific American takes pleasure in passing on some of the contributions in the 70th anniversary collection to more of Bohr's legion of friends everywhere.

On the Feasibility of Coal-driven Power Stations

by O. R. Frisch

[*Editors' note: The following article is reprinted from the Yearbook of the Royal Institute for the Utilization of Energy Sources for the Year 4995. In view of the acute crisis caused by the threat of exhaustion of uranium and thorium from the Earth and Moon Mining System, the Editors thought it advisable to give the new information contained in the article the widest possible distribution.*]

Introduction. The recent discovery of coal (black, fossilised plant remains) in a number of places offers an interesting alternative to the production of power from fission. Some of the places where coal has been found indeed show signs of previous exploitation by prehistoric men who, however, probably used it for jewels and to blacken their faces at tribal ceremonies.

The power potentialities depend on the fact that coal can be readily oxidised, with the production of a high temperature and an energy of about 0.0000001 megawattday per gramme. That is, of course, very little, but large amounts of coal (perhaps millions of tons) appear to be available.

The chief advantage is that the critical amount is very much smaller for coal than for any fissile material. Fission plants become, as is well known, uneconomical below 50 megawatts, and a coal-driven plant may be competitive for communities with small power requirements.

Design for a Coal Reactor. The main problem is to achieve free, yet controlled, access of oxygen to the fuel elements. The kinetics of the coal-oxygen reaction are much more complicated than fission kinetics, and not yet completely understood. A differential equation which approximates the behaviour of the reaction has been set up, but its solution is possible only in the simplest cases.

It is therefore proposed to make the reaction vessel in the form of a cylinder, with perforated walls to allow the combustion gases to escape. A concentric inner cylinder, also perforated, serves to introduce the oxygen, while the fuel elements are placed between the two cylinders. The necessary presence of end plates poses a difficult but not insoluble mathematical problem.

Fuel Elements. It is likely that these will be easier to manufacture than in the case of fission reactors. Canning is unnecessary and indeed undesirable since it would make it impossible for the oxygen to gain access to the fuel. Various lattices have been calculated, and it appears that the simplest of all—a close packing of equal spheres—is likely to be satisfactory. Computations are in progress to determine the optimum size of the spheres and the required tolerances. Coal is soft and easy to machine; so the manufacture of the spheres should present no major problem.

Oxidant. Pure oxygen is of course ideal but costly; it is therefore proposed to use air in the first place. However, it must be remembered that air contains 78 per cent of nitrogen. If even a fraction of that combined with the carbon of the coal to form the highly toxic gas cyanogen this would constitute a grave health hazard (see below).

Operation and Control. To start the reaction one requires a fairly high temperature of about 988 degrees F.; this is most conveniently achieved by passing an electric current between the inner and outer cylinder (the end plates being made of insulating ceramic). A current of several thousand amps is needed, at some 30 volts, and the required large storage battery will add substantially to the cost of the installation.

Once the reaction is started its rate can be controlled by adjusting the rate at which oxygen is admitted; this is almost as simple as the use of control rods in a conventional fission reactor.

Corrosion. The walls of the reactor must withstand a temperature of well over 1,000 degrees F. in the presence of oxygen, nitrogen, carbon monoxide and dioxide, as well as small amounts of sulphur dioxide and other impurities, Standard form FT/3.

Title: .... in field theory.

Author: ....

According to Schwinger

(1)

whence

(2)

hence

(3)

Thus[1)]

(4)

which is not inconsistent with the assumption that

(5)

In virtue hereof

(6)

whence

(7)

hence

(8)

Thus, from a formal point of view

(9)

It is hoped that this kind of argument may lead to the most general formulation of the problem of ghost states.

The author is .... valuable criticism.

1) Cf. also Källen, Ark. f. astr., mat. och fys. ....

STANDARD FORM for a paper in quantum field theory was designed by J. Lindhard and P. Kristensen of the University Institute for Theoretical Physics in Copenhagen. The blanks labeled with the numbers in parentheses at the right are for equations. "Schwinger" is Julian Schwinger of Harvard University, one of the principal workers in quantum field theory.

some still unknown. Few metals or ceramics can resist such grueling conditions. Niobium with a thin lining of nickel might be an attractive possibility, but probably solid nickel will have to be used. For the ceramic, fused thoria appears to be the best bet.

Health Hazards. The main health hazard is attached to the gaseous waste products. They contain not only carbon monoxide and sulphur dioxide (both highly toxic) but also a number of carcinogenic compounds such as phenanthrene and others. To discharge those into the air is impossible; it would cause the tolerance level to be exceeded for several miles around the reactor.

It is therefore necessary to collect the gaseous waste in suitable containers, pending chemical detoxification. Alternatively the waste might be mixed with hydrogen and filled into large balloons which are subsequently released.

The solid waste products will have to be removed at frequent intervals (perhaps as often as daily!), but the health hazards involved in that operation can easily be minimized by the use of conventional remote-handling equipment. The waste could then be taken out to sea and dumped.

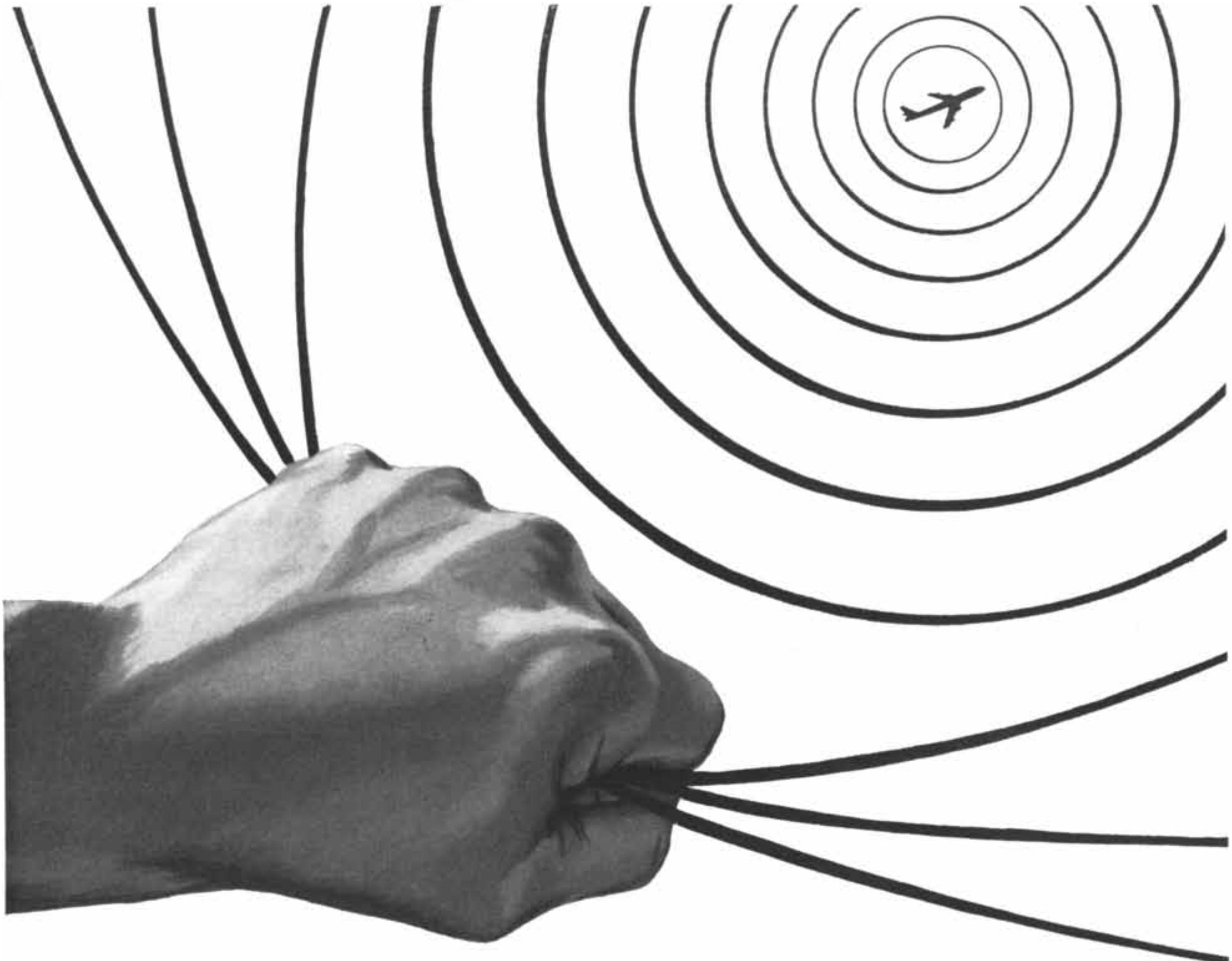
There is a possibility—though it may seem remote—that the oxygen supply may get out of control; this would lead to melting of the entire reactor and the liberation of vast amounts of toxic gases. Here is a grave argument against the use of coal and in favor of fission reactors which have proved their complete safety over a period of several thousand years. It will probably take decades before a control system of sufficient reliability can be evolved.

A Key to the Key Theory

Anonymous

It has been remarked that the key system is more complicated than field theory. In order to refute this misinterpretation of facts it is felt worthwhile to present a simplified version of the method by which the key system was derived.

First we must define: A key consists of a rod with small pins (*see illustration on page 96*). A lock consists of a slit with small holes in positions corresponding



Stretching the Path of an Electronic Pulse

Military coding equipment takes one pulse and inserts it into a delay line and in effect sends it over a number of paths, each of different lengths. Combining the output of the paths gives a pulse train with pulses spaced in accordance with artificial length of the path. Ordinarily the flexibility of the equipment is limited by the fixed taps in the delay line and the accuracy is established by auxiliary circuitry.

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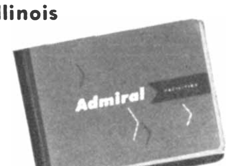

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to the positions of the pins plus a system of levers behind the small holes (*see illustration*).

We then introduce three axioms: (1) The pins move the levers; all levers in a lock must be moved in order to open the lock. (2) There may be pins, holes and/or levers in positions where there are no pins, holes and/or levers. We define further: If there is no pin, hole or lever in a given position we talk about unpins, unholes and unlevers. (3) No locks have levers behind unholes, because such a lock could never be opened.

Pins, holes and levers are described by the value 1 for the variables a_i, b_i and c_i respectively. The index i refers to the position. Unpins, unholes and unlevers are described by the value 0 for the same variables. We then define the following matrix multiplication

$$(a_1\ a_2 \dots a_k)\begin{pmatrix} b_1 & b_2 \dots b_k \\ c_1 & c_2 \dots c_k \end{pmatrix} = (a_1 b_1 c_1\ \ a_2 b_2 c_2 \dots a_k b_k c_k) \qquad (1)$$

where the symbolic product $abc = a$ if $a \leqslant b$ and simultaneously $a \geqslant c$, otherwise $abc = 1 - a$. It then follows that if $(a_1\ a_2 \dots a_k)$ is an eigenvector for the operator

$$\begin{pmatrix} b_1 & b_2 & \dots & b_k \\ c_1 & c_2 & \dots & c_k \end{pmatrix}$$

the key can open the lock.

By means of this formalism it is readily deduced that the number of keys that will open a given lock

$$\begin{pmatrix} b \\ c \end{pmatrix}$$

equals

$$N_K = \left(2^{\Sigma(b_i - c_i)}\right)K \qquad (2)$$

and the number of locks that will be opened by a given key (a) equals

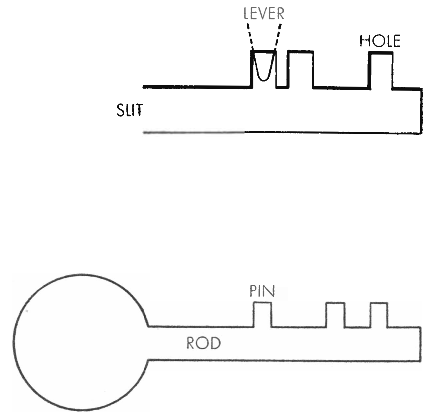
$$N_L = \left(2^{\Sigma a_i} - 1\right)K \qquad (3)$$

taking into account that the special lock

$$\begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

is a trivial unlock. In equations (2) and (3) K is a sum of Clebsch-Gordon coefficients equal to unity.

The following problems were now solved. If somebody wants to go from room A to room B the necessary number of keys was maximized for any choice of A and B. The minimum problem was not chosen because it is trivial. Next the



NOT UNCOMMON CASE of a key that does not fit the lock is illustrated. The key is at the bottom. The lock is shown at the top.

group of members at the Institute was divided into a number of subgroups and the key system was designed according to the following two principles: 1. No subgroup may be able to open all those locks which can be opened by any other subgroup. 2. The transformation properties of the group correspond to the possibility of borrowing keys.

It was hoped that this system of keys was unique and complete, which it also is in a certain sense, but it happens that a key not supposed to open a door can do so if it is not introduced into the lock in its full length. As an example the key (1 1 1 1 1) can open the lock

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix}$$

in $n = 5$ different positions. The number n is called the strangeness of the system key plus lock. By an experimental investigation it was found that the present system is very strange. It is suggested that this is remedied by demanding that $a_k = b_k = c_k = 1$ for the last position.

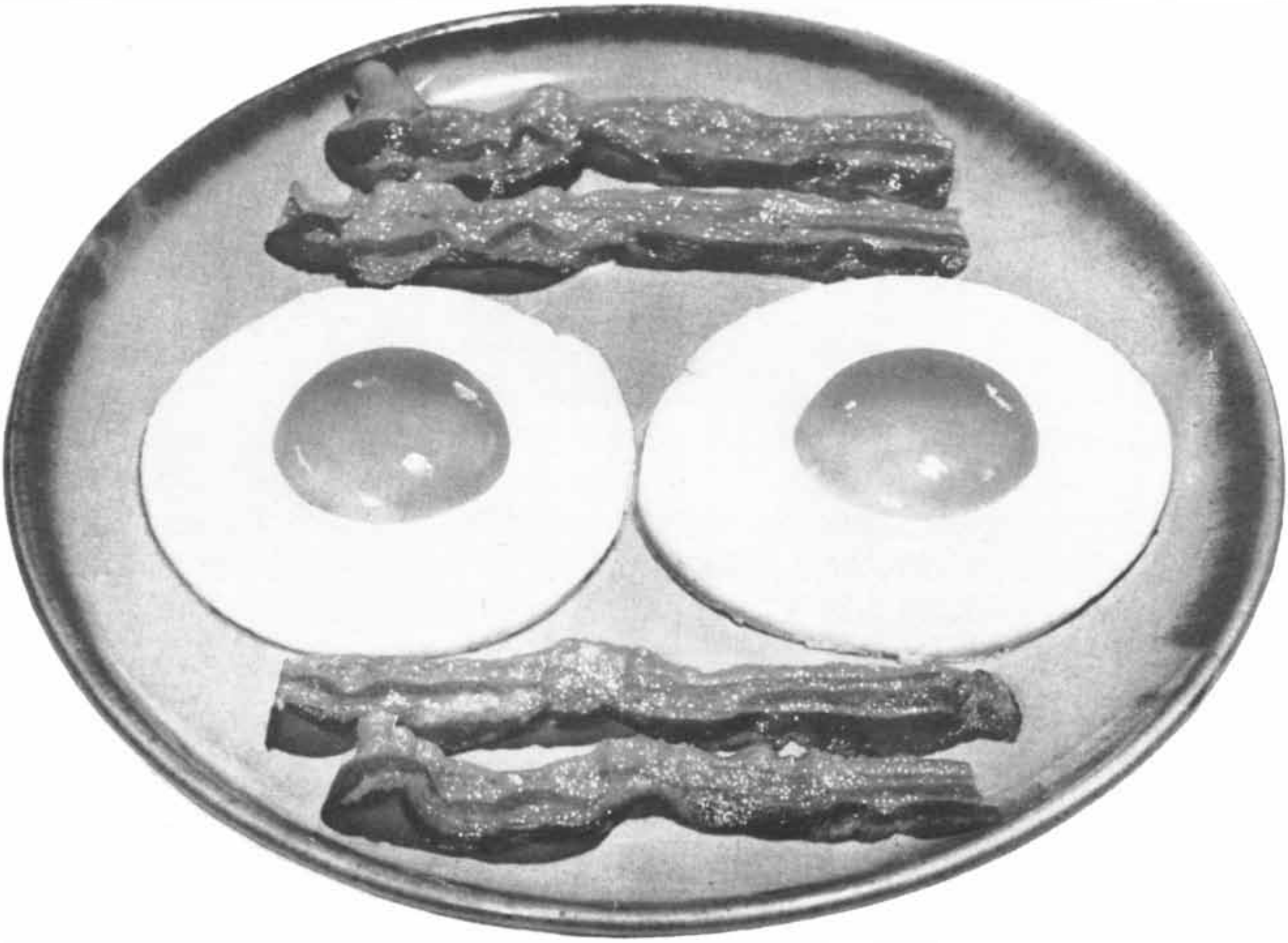
Skeleton keys fall outside the scope of the present investigation.

The author wants to thank numerous group members for many heated discussions on the present subject.

Broken English

by H. B. G. Casimir

There exists today a universal language that is spoken and understood almost everywhere: it is Broken English. I am not referring to



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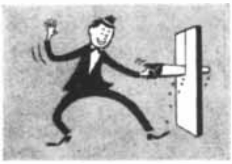

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Pidgin English—a highly formalized and restricted branch of B. E.—but to the much more general language that is used by waiters in Hawaii, prostitutes in Paris and ambassadors in Washington, by businessmen from Buenos Aires, by scientists at international meetings and by dirty-postcard peddlers in Greece—in short by honorable people like myself all over the world.

One way of regarding Broken English is to consider it as a more or less successful attempt to speak correct English, but that is a pedantic, schoolmasterish point of view that moreover threatens to stultify the speaker of B. E. and to deprive his language of much of its primeval vigor. Of course a corresponding point of view would be entirely justified in the hypothetical case of an Englishman trying to speak Dutch (or any other language for that matter) because he will necessarily be a lone figure, but the number of speakers of Broken English is so overwhelming and there are so many for whom B. E. is almost the only way of expressing themselves—at least in certain spheres of activity—that it is about time that Broken English be regarded as a language in its own right. It is then found that B. E. is a language of inexhaustible resources—rich, flexible and with an almost unlimited freedom. In the following I shall try to establish some of the fundamental principles of B. E. in the hope that others, more qualified than myself, will take up the subject and help to secure for it the prominent place in linguistics to which it is justly entitled.

Phonetics. The immense richness of B. E. becomes at once evident if we try to represent its sounds. Two short lines of keywords (44 in all) at the bottom of a page of a 25-cent Merriam-Webster are a sufficient clue to the pronunciation of standard American. And the famous English pronouncing dictionary of Jones has only 35 keywords. Compare these pedestrian figures with the wealth of sounds current in B. E. The whole international phonetic alphabet is hardly sufficient to meet the case. Take one simple letter like *r*. It may sound like an Italian *r* beautifully rolling on the tip of the tongue, like a guttural Parisian *r* or like no *r* at all. In this last case the speaker usually suffers from the illusion that he speaks pure Oxford English. Similarly *th* may sound as a more or less aspirated *d* or *t* or as a simple *z* and sometimes (especially in the case of Greeks) almost like *th*. Then there are elements entirely foreign to English, like the Swedish musical accent and the Danish glottal stop

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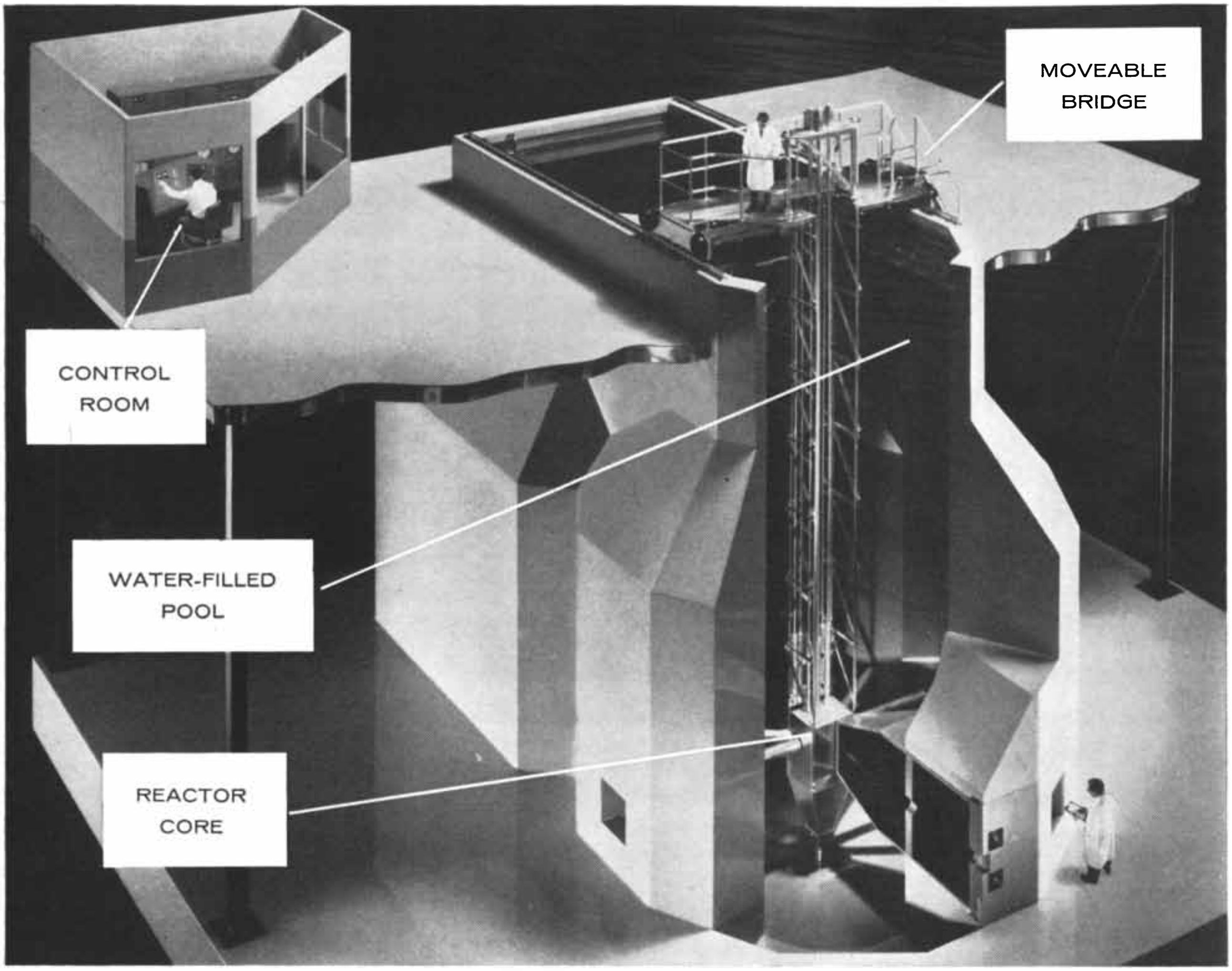

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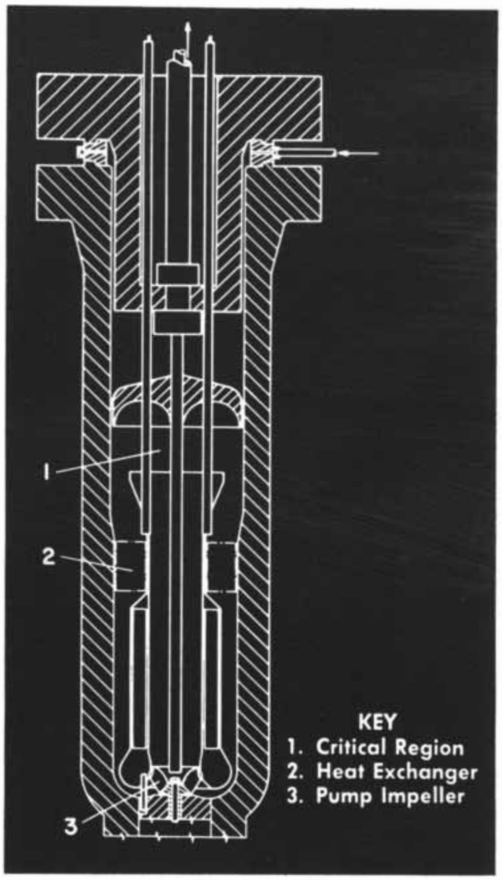

(some people pretend that the glottal stop is hard to pronounce but that is nonsense; it is very easy in itself and gets only difficult if you try to put it into a word).

But even more important is the principle of free choice. It is well known that the combination *ough* can represent at least five different sounds. The educated speaker of B. E. is well aware of this fact; but, whereas the speaker of standard English can only use one pronunciation in one word, the speaker of B. E. is at complete liberty. Some speakers make their choice once for all: they decide that they are going to pronounce doughnut as duffnut and stick to it. Others may use their freedom in a more subtle way and say duffnut or dunut depending on the hour of the day or the weather. Still others create distinctions and say dunut when referring to pastry but downut (like in plow) when referring to a circular discharge tube used in modern physical apparatus. The pronunciation dupnut (like in hiccoughs) is rarely heard, although it is certainly correct B. E. It is dubious however whether donut (like in go) is acceptable.

Then there is the accent. In standard English this is a queer business. During the development of the English language the accent has had a tendency to move to the front of a word, but it has not gone all the way and it has shown a curious inclination to linger on the most irrelevant and meaningless syllable of a word. Words like barometer and turbidity will illustrate the point. Whether this is one more example of the traditional British sympathy for the underdog I do not know, but the result is baffling and to the convinced speaker of B. E. the realization that he has nothing to do with these weird intricacies comes as a great relief. The *dogmatics* will use their freedom by putting the accent always on the first syllable, whereas the *rationalists* will stress what seems to them the most important syllable. The *quixotics* try to imitate standard English. This is obviously impossible, but the result has sometimes a certain slightly pathetic charm.

Grammar. Much of what is said about phonetics applies to grammar too. Again a great richness, again a principle of free choice. The gain in power of expression that can be derived from, for example, a judicious use of the article is impressive. If a man invites you to a party it may very well turn out to be a dull show, but if he says, "Today we will have party and shall drink the cocktail,"

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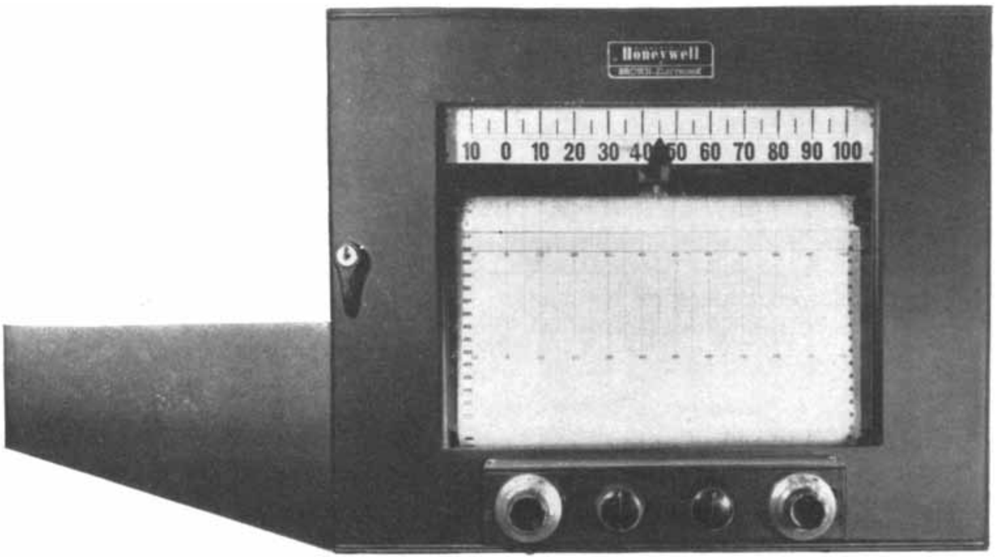

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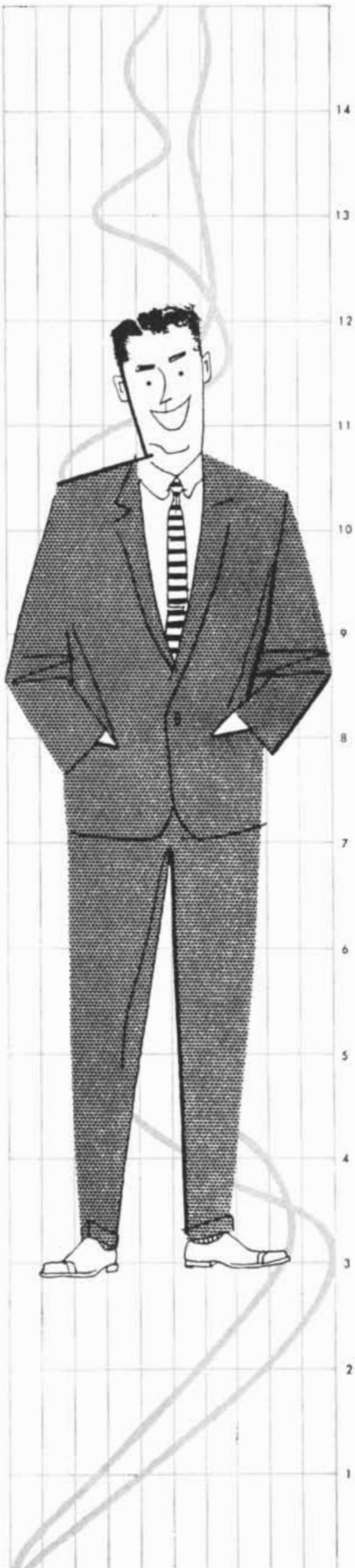


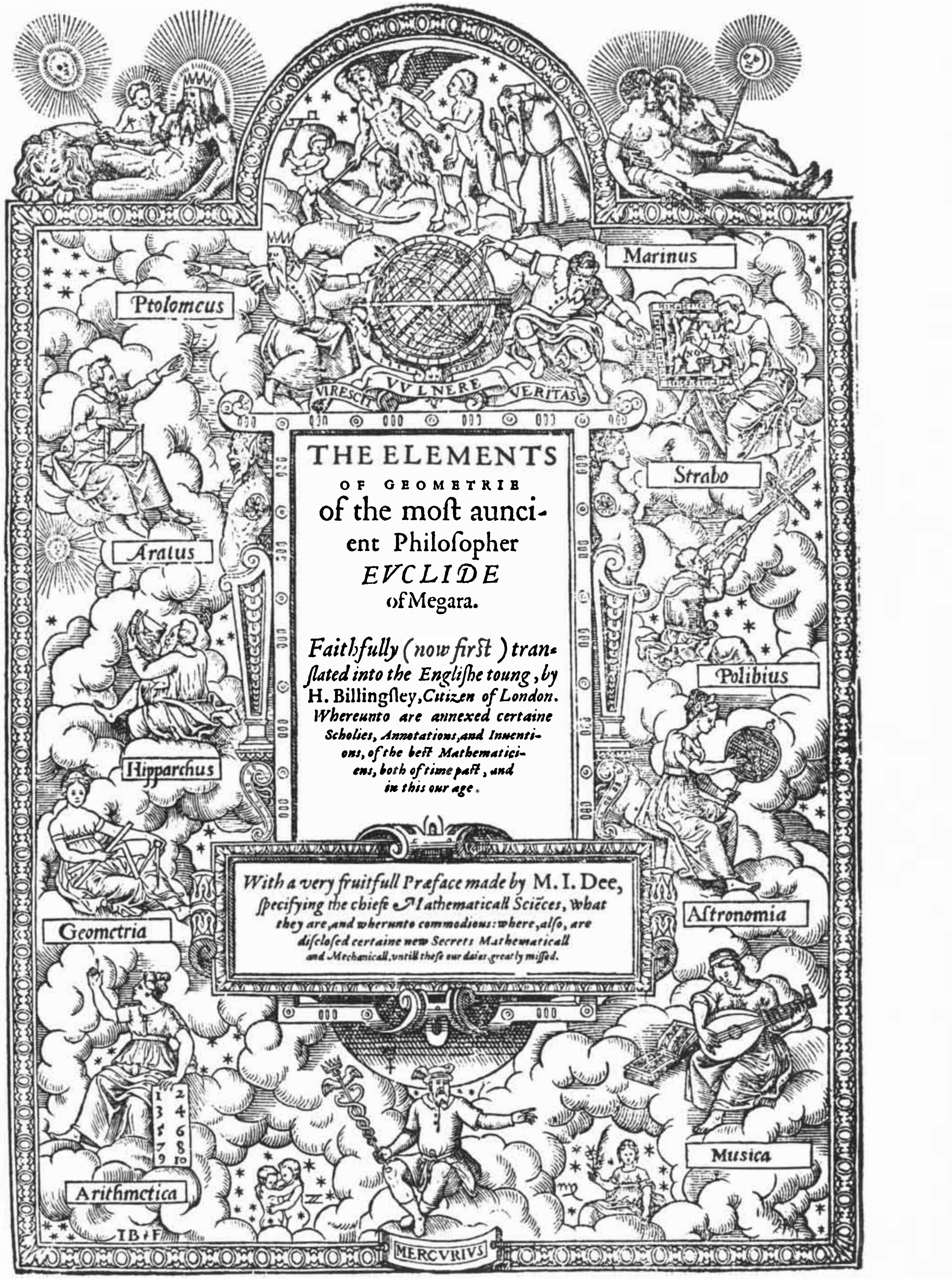
you can almost be certain that you are in for a lively time. Changing the sequence of words gives new flavor to old sayings—"this is the moment when the frog into the water jumps," one of my teachers used to say at the critical spot in a mathematical proof. Although past tenses and third persons are entirely superfluous, it should be emphasized that occasionally brilliant effects can be obtained by borrowing a correctly inflected verb from standard English.

Vocabulary. Also here there is a great freedom. Of course complete Humptydumptyism is impossible, but B. E. is the closest approach compatible with a measure of understandability. (To explain the term Humptydumptyism: "The question is," said Alice, "whether you can make words mean different things." "The question is," said Humpty Dumpty, "which is to be master, that is all.") It is characteristic of the genius of Lewis Carroll that he, who was by birth and breeding excluded from obtaining a mastery of Broken English, came by sheer artistic intuition so close to one of its basic principles.

Notwithstanding the great liberty in the use of words, there is one case where all speakers of B. E. seem to agree: in Broken English Broken English is called just "english."

Idiom. It is remarkable how old and trite sayings in any ordinary language may acquire new glamour when translated into B. E. The only danger is that one may unintentionally come to use an existing English proverb. "Who burns his buttocks must sit on the blisters" sounds all right to me, but heaven knows whether a similar saying does not exist in Standard English. As a matter of fact this is always a grave peril also with respect to phonetics and grammar: one may lapse unawares into trivially correct standard English.

I am afraid that this very short survey will have to do for the present. But I have still two important remarks to make. Firstly: in view of the stupendous wealth of B. E. it will at once be evident how completely ridiculous, ludicrous, preposterous and ill-advised are the attempts to introduce for use by foreigners a so-called Basic English, a language nót richer but even poorer than standard English. Secondly: it is often stated that at the age of 16 or so one loses the faculty to learn English correctly. This again is entirely wrong: nothing of any importance is lost; what is gained is the faculty to create one's own brand of Broken English.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THE STRAIGHT LINE

Euclid's definition of it is worthless, but his axioms remain basically sound. His successors in mathematics have extended his ideas to the curved line and a clearer concept of length

by Morris Kline

We often mistake familiarity for understanding, but of course they are not the same thing. For example, every wife is familiar with her husband but certainly does not understand him, as every husband will certify. Among the subjects we suppose we understand, nothing would seem less complicated than the straight line. It is so familiar and so obvious that it hardly seems worth talking about. And yet the fact is that mathematicians have found the straight line a most complex and subtle study, and it has taken hundreds of years of analysis by many brilliant minds to arrive at a full understanding of it as a logical concept.

The straight line is easy enough to picture in physical terms—*e.g.*, a string stretched taut between two points, the edge of a ruler, and so on. But these devices do not answer the question: What is the mathematical straight line? The mathematical line has no thickness, no color, no molecular structure. It is an abstraction—an idealization of the ruler's edge and the stretched string. What properties does the mathematical straight line possess?

Euclid attempted to define it in this manner: "A straight line is a curve which lies evenly with the points on itself." He defined a curve (line) as length without thickness, and a point as something having no "parts." But he failed to define either length or part, so that his definition rests upon physical conceptions and is therefore not acceptable as a mathematical definition, for mathematical logic must be independent of physical meanings. Furthermore, the phrase "lies evenly with the points on itself" is completely mysterious. We must conclude that Euclid's definition is worthless.

If this is so, how was Euclid able to proceed with the construction of a logical system of geometry? The answer is that, as mathematicians now realize, any logical system must start with undefined concepts, and it is the axioms of the system, and only these, that specify the properties of all the concepts used in the proofs. Without being at all aware of this, Euclid did the right thing: he ignored his worthless definitions of point, curve and straight line, so that in effect these concepts were undefined, and he proceeded to state the 10 axioms of his geometry.

His axioms state, among other things, that a straight line is determined by two points, that it may have indefinite length, that any two right angles are equal, that only one line parallel to a given line can pass through a point outside that line in the same plane, that when equals (*e.g.*, equal line segments) are added to equals the sums are always equal, and that the whole is greater than any of its parts. From these axioms Euclid deduced hundreds of theorems which tell us much more about the mathematical straight line.

As we examine these axioms and theorems, we nod our heads in agreement and in approval. Euclid does seem to have described the essence of the straight line. The straightness of the ruler's edge and the stretched string are apparently bound fast in his system of geometry; in particular, the shortest distance between any two points in the space described by his geometry is a straight line. (Incidentally, this fact is not axiomatic, as commonly supposed, but is a deep mathematical theorem.)

But now, as we explore further, we meet a disturbing fact. Consider a curved surface such as the one shown on the next page [*Figure 1*]. The shortest path between two points on this surface is not a straight line in the usual intuitive sense. And yet the surprising fact is that such paths and figures formed by them on this surface obey all the axioms of Euclidean geometry! For example, the axiom of parallel lines applies here: given a curve which represents the shortest distance between two points on the surface (this curve is called a geodesic), we can draw only one geodesic through a point not on this curve which will never meet the first geodesic however far the two curves are extended.

The point of this model is that Euclid and all the mathematicians who accepted Euclidean geometry until recent times believed erroneously that the Euclidean axioms and theorems applied only to the straight lines formed by rulers' edges and stretched strings. But now we find that the axioms and theorems also apply perfectly to figures on a curved surface. The situation is analogous to that of a client who asks an architect to design a house according to certain instructions and then finds when the house is built that it does not look at all like what he had envisioned, although the architect obeyed his instructions as far as they went. The trouble is that his instructions were not sufficiently restrictive. So it is with Euclid's axioms. They give so much leeway that they describe curved lines as well as straight ones.

In the early years of the 19th century mathematicians, though not yet concerned with the flaws we have just ex-

FIRST SCIENTIFIC BOOK published in English was Henry Billingsley's 1570 translation of Euclid's *Elements*, the title page of which is shown on the opposite page. Billingsley later was Lord Mayor of London.

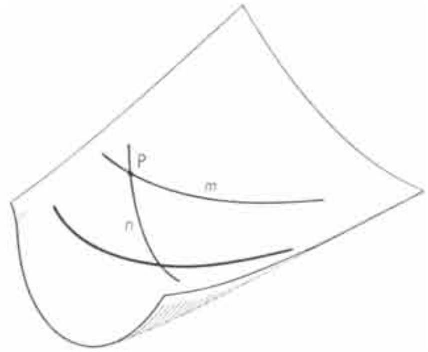


Figure 1

amined, attacked the Euclidean axioms on other grounds. They were troubled by Euclid's assumption that a pair of lines might never meet however far they were extended in space. They believed that they should not postulate so boldly what happens in regions inaccessible to experience. Hence they sought to replace this axiom by an axiom intuitively more acceptable or more readily verifiable. But every proposed substitute for the parallel axiom was found on analysis to involve assumptions about space as objectionable as the Euclidean parallel axiom. Whereupon some mathematicians adopted an entirely new course.

The first of these innovators, the Jesuit priest Girolamo Saccheri, had set out to prove that Euclid's axiom was the only possible correct one by showing that any other parallel axiom contradicting his would lead to a contradiction in the resulting system of geometry. First he was able to show that such contradictions would arise if one proposed the axiom that there is *no* parallel to a given line through a point not on this line. Then he examined the proposition that *more than one* parallel to the line might pass through such a point. In this case he arrived at no outright logical contradictions, but the theorems he derived were so strange that he concluded this system of geometry made no sense.

Saccheri, it turned out, had given in too easily. The system based on his second axiom was soon shown to be less absurd than it seemed. The great mathematicians Karl Friedrich Gauss, Nikolai Lobachevski and János Bolyai, working independently, created a non-Euclidean geometry, which is named for Lobachevski because he was the first to publish the results. This geometry was built, in effect, upon Saccheri's more-than-one-parallel axiom and the other nine Euclidean axioms.

In considering the Lobachevskian geometry the reader must remember that we are dealing with mathematical abstractions, not with physical objects. Some of the theorems and conclusions may seem at first sight to defy common sense, or the evidence of our senses. However, all we can ask of a logical system is that it be rigorously logical and consistent within itself. As a matter of fact, it is found upon analysis that the new non-Euclidean geometries agree with physical observations as well as Euclidean geometry does.

In this vein let us compare the Lobachevskian and Euclidean straight lines. We start with a line tangent to a hyperbola at the vertex [*Figure 2*]. In Lobachevski's geometry, as a consequence of his axioms, the length of the segment AB of this line has a value which corresponds numerically to the area A′OB′ in the Euclidean system. (The proof of this equality need not concern us here.) Similarly the line segment AC is equal to the area COA′. Now let us

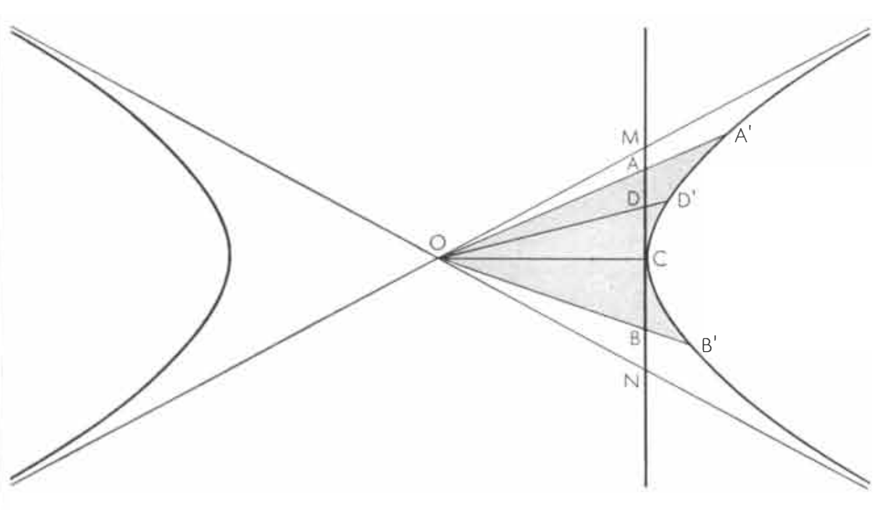
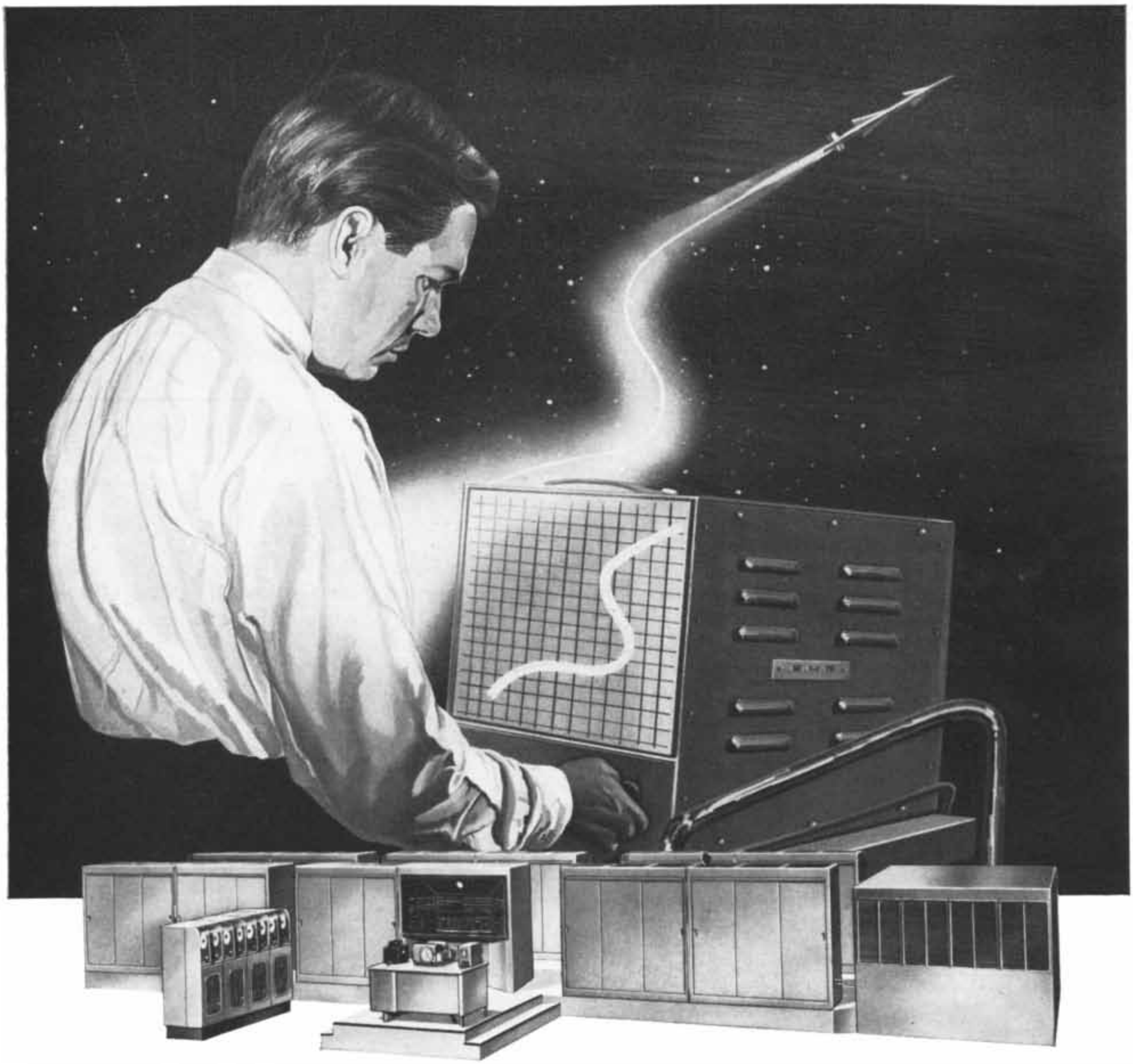


Figure 2



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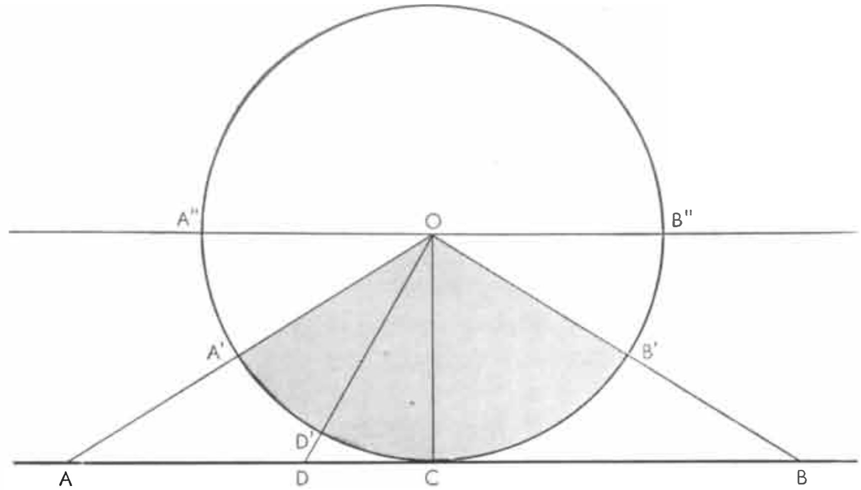


Figure 3

suppose that the area COD′ equals the area D′OA′. This being so, in Lobachevskian geometry the line segment AD must be equal to the segment DC, although in Euclidean geometry their lengths are obviously different. There are still more remarkable consequences. As we move point *A* closer to *M*, the area COA′ increases rapidly, and so does the numerical value of the line CA. If the line OM is tangent to the hyperbola at infinity (what is called an asymptote), then the area becomes infinite when *A* reaches *M*, and the length of the line CM likewise is infinite, according to the Lobachevskian geometry. Thus the entire straight line of Lobachevski's geometry, though infinite in length as far as his system is concerned, is represented within the finite Euclidean line MN.

What this comparison of the Euclidean and Lobachevskian lines teaches us is that the Euclidean mathematicians were parochial in their understanding of equality, or "congruence." The Euclidean axioms concerning the equality or inequality of line segments were framed with the concept of rigid bodies in mind. Euclid intended that equal segments be those which yielded the same lengths when measured by a rigid ruler, and mathematicians followed his lead. But the Lobachevskian line shows that line segments may be equal in spite of the fact that a rigid ruler indicates them to be unequal.

This fact suggests that even the Euclidean concept of equality may have entirely new physical interpretations. Suppose that as we moved out toward the ends of the universe our measuring rod contracted more and more, and all physical objects and distances shrank in the same proportion. We would be unaware of the contraction, and would believe that we were living in an infinitely extended world, although actually it might be finite, as measured by a truly rigid ruler. In other words, just as soon as we recognize that the Euclidean equality axioms can be satisfied with a new physical meaning for equality, we must recognize also that the physical world which appears to be Euclidean may actually possess quite a different structure.

Bernhard Riemann conceived another non-Euclidean geometry which took the opposite tack from Lobachevski's. He started with Saccheri's first proposition—that there are no parallel lines to a given line—and with the remaining nine axioms of Euclid, modified in minor respects. In Riemann's geometry the straight line proves to be *finite* in length and to have the structure of a circle.

We can illustrate the difference between the Riemannian line and the Euclidean line with another diagram [*Figure 3*]. Here a Euclidean line is tangent to a circle, and we consider the segment AB. In Riemann's geometry the length of AB turns out to be equal *numerically* to the Euclidean area A′OB′ within the circle (the shaded area in the figure). As a consequence of this fact, if the area

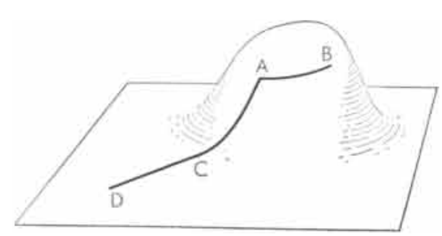
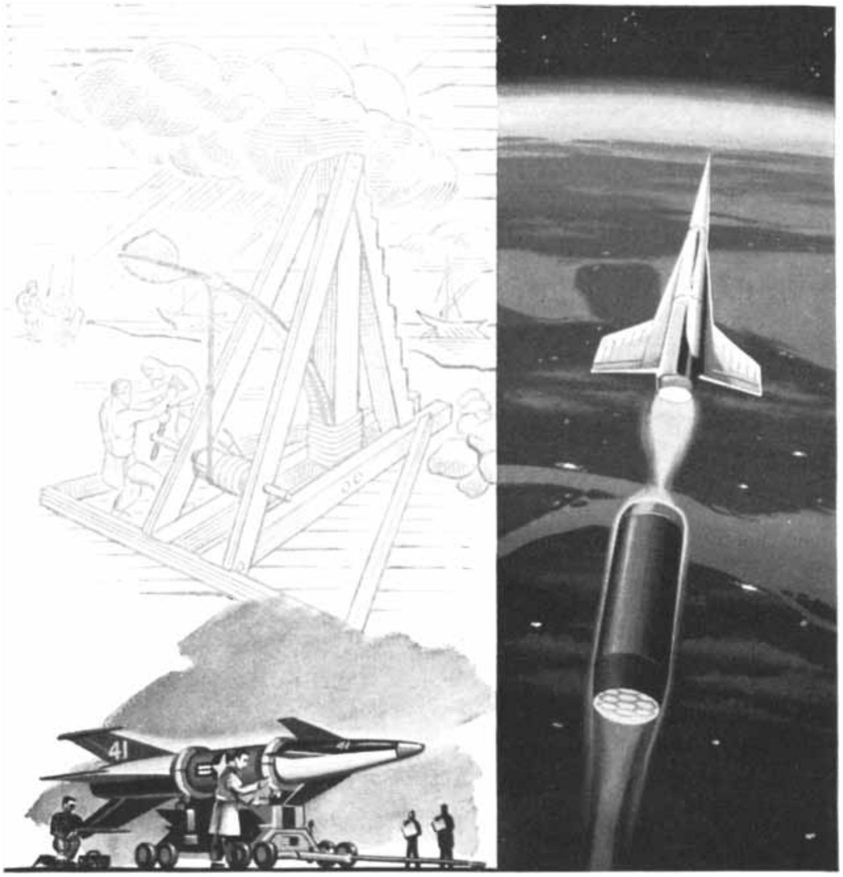


Figure 4



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COD′ equals the area D′OA′, for example, the line segment CD is equal to DA, although by Euclidean standards the latter is much longer than the former. Now however far we may move *A* to the left and *B* to the right, the length of AB cannot exceed the area of the semicircle below A″B″; that is, the Riemannian line has finite length. The interpretation also suggests how an infinite world could be represented by a geometry with finite lines. Whereas with a contracting measuring rod a finite world might appear infinite, with an expanding measuring rod an infinite world would appear finite.

The farther we pursue the theorems of the non-Euclidean geometries, the more their straight lines affront our intuition and incite us to rebel. And yet, if we object to the finiteness of the Riemannian line and its circular structure on the ground that our view of the universe calls for lines extending indefinitely far out into space, a mathematician can reply that this notion is merely the product of an unbridled and untutored imagination. Within the actually observable world of our experience the non-Euclidean geometries furnish an accurate description of physical realities.

The "straight line" in all geometries has the same basic definition: the shortest distance between two points. This is true whether we consider a stretched string, an arc on the surface of a sphere or even a more complex path. Let us take the case of a round hill standing on a flat plain [*Figure 4*]. The shortest path between two points around the brow of the hill (AB) may be the arc of a circle; the shortest path from *A* to *C* at the base of the hill may be a rather flattened S curve; from *C* to *D* on the plain we have an ordinary straight line. If one were to construct a geometry to fit this surface, the "straight" line of this geometry would have to have the properties common to AB, AC and CD—that is, the properties of the various geodesics on this surface. Obviously construction of such a geometry would not be simple.

In the geometry of the theory of relativity the paths of light rays in space-time are the geodesics, and these play the role of the straight line. The geodesics are generally not straight. In fact, this geometry possesses some of the peculiarities of a flat region containing hills. Each mass in space-time (*e.g.*, the sun) acts like a hill causing the geodesics to depart from straightness.

Suppose now we turn from the vast realm of space to minute segments of the straight line. What does mathe-

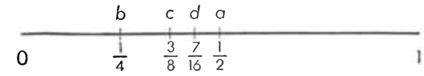


Figure 5

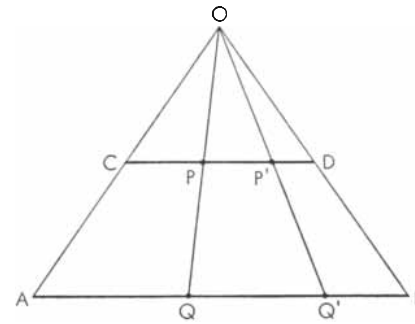


Figure 6

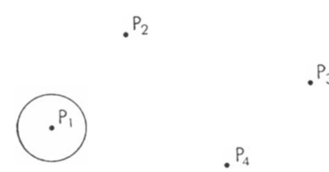


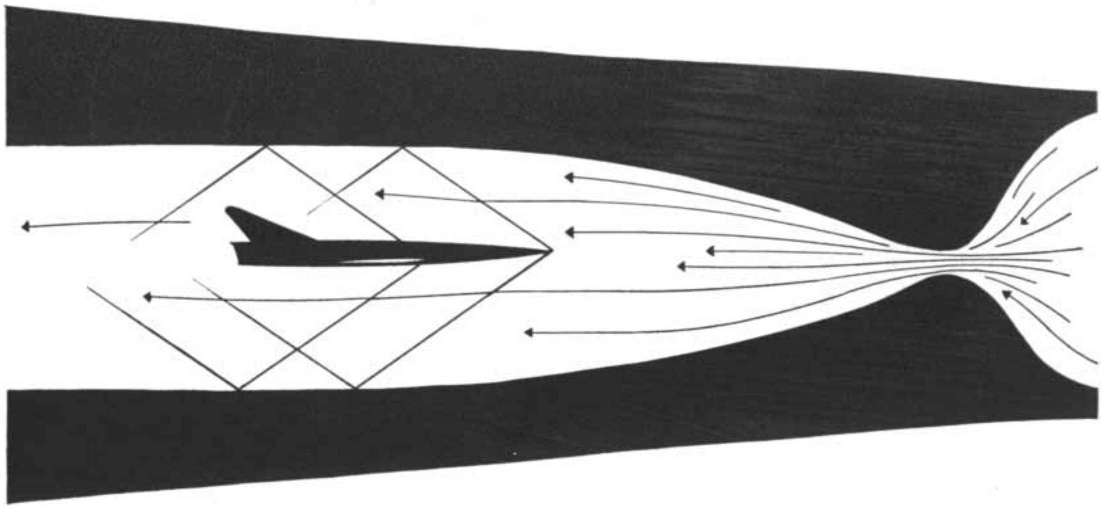
Figure 7

matics have to say about the internal structure of a segment?

Intuition and Euclidean geometry agree that we may divide this segment into any given number of equal parts. If we labeled the midpoint 1/2, then marked the quarters, divided the segment again into eighths [*Figure 5*] and continued unendingly to halve the successively smaller segments, it would appear that eventually we could label every point on the line. A moment's thought makes clear, however, that this is impossible. For one thing, there is an infinite number of fractional lengths not included in the foregoing set (*e.g.*, 1/3, 1/5). For another, we must also consider fractional lengths corresponding to the irrational numbers (half the square root of 2, one-third the square root of 2, and so on) which are also infinite in number and terminate at other points on the line. As a matter of fact the unit segment contains more irrational points than rational points. The entire collection of points on the segment is called the continuum—the "grand continuum" in the words of the mathematician J. J. Sylvester.

Now consider a line twice as long as

Guided Missile Engineers and Scientists



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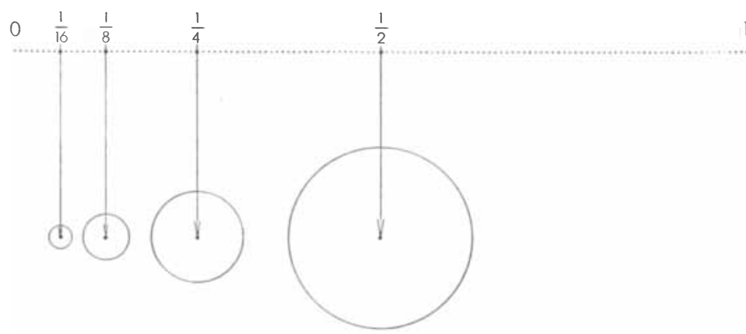

Figure 8

the preceding unit. One would expect it to contain twice as many points. But paradoxically it has exactly the same number of points. This is easily proved by forming a triangle with the longer line as the base and the shorter one as the midline [*Figure 6*]. Now if we draw lines from the apex of the triangle through the midline to the baseline, we can see that for every point crossed in the former, there will be a unique corresponding point in the latter. Thus there is a one-to-one correspondence between the points on CD and on AB. But one-to-one correspondence is precisely the basis for asserting the equality of the number of objects in two sets of objects. If an army of soldiers each carrying a gun were to pass in review before us, we would know at once that there are as many guns as soldiers.

If all line segments contain the same number of points, how can they differ in length? This question was raised in a more general form more than 2,000 years ago by the Greek philosopher Zeno. Magnitude, said Zeno, must be divisible. Points, being indivisible, can possess no magnitude. A line segment, then, being made of points which have no magnitude, cannot itself have magnitude, any more than a noise can be a composite of silences. In other words, how can length arise from a conglomeration of points which have no length?

Modern mathematics has taken up and answered this question by introducing the "theory of measure," by which, through assigning lengths to rather arbitrary sets of points on a line, the paradox is resolved. We need not go into the process here; it is sufficient to say that the method has enabled us to penetrate somewhat into the murky darkness of the interior of the straight line.

The straight line is the starting point for another deep investigation which has come to fruition within the last quarter century. The subject in question was clearly in Euclid's mind when he defined a curve (line) as breadthless length and then stated that its extremities are points. He was saying in effect that the line is one-dimensional and the point zero-dimensional. The line is not a band or strip. But breadthless length, we saw, is a physical definition and hence not acceptable to mathematics. Just what do we mean by the intuitive or physical statement that a line is one-dimensional?

The full answer is a long story, but the essential idea is as follows. Let us ask the more general question: What shall we mean by the dimension of any set of points in a Euclidean plane? To begin with, suppose that we have a set of points whose dimension is to be determined. We surround the points of the set by small circles. If by making the circles sufficiently small we can avoid intersecting any points, then the set is said to be zero-dimensional. Thus, to take a trivial example, if the given set consists of a finite number of distinct points, we could certainly surround all these points by arbitrarily small circles which do not run through any point of the set [*Figure 7*]. Hence a finite set of points is zero-dimensional. Likewise the infinite set of points whose labels are 1, 1/2, 1/4, 1/8, . . . is zero-dimensional [*Figure 8*].

We can now define one-dimensional sets in terms of zero-dimensional sets. A set of points, whether on a line or in a plane, is one-dimensional if it is not zero-dimensional and if arbitrarily small circles surrounding each point of the set can be found which cut the set in a zero-dimensional set of points. Thus if we consider a straight line as the set of points whose dimension is to be determined, then we note that any circle surrounding a point of the line cuts the line

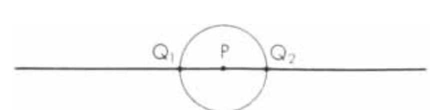

Figure 9

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Figure 1 shows a typical magnetization curve of an electromagnet with a flux density of 20,000 gausses, when the polarizing force is 200 oersteds. (The curve has been displaced into the magnetizing quadrant for comparison purposes.)

In a well-designed electromagnet, approximately half the total area is occupied by conductors, and half is flux-conducting core material.

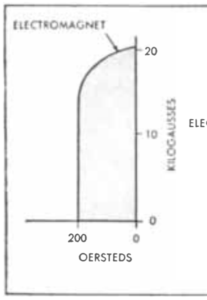

FIGURE 1

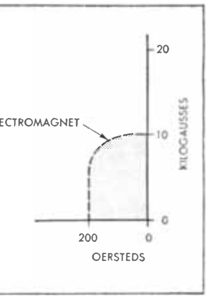

FIGURE 2

Therefore, to make the comparison valid, the residual induction of the electromagnet must be reduced to 10,000 gausses (Figure 2).

The area under the curve now represents the approximate external field energy available on a volume basis. When the equivalent demagnetization curve of Alnico 5 is plotted against the corrected electromagnet curve (Figure 3), the true capabilities of each type of magnet become immediately apparent.

The area under the Alnico 5 curve is about three times the area under the electromagnet curve. Thus, to produce a given field requirement, the permanent magnet will occupy a volume one-third that of an equivalent electromagnet.

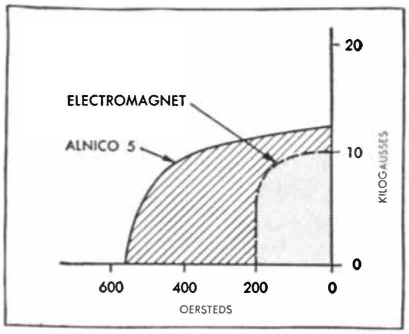

FIGURE 3

The above comparison is somewhat theoretical; under many circumstances, permanent magnets will show to even greater advantage. For example, consider the two TV-tube focusing magnets in Figure 4, at the top of the next column.

At the left, is the electromagnet previously used. It weighed 2 lbs. 13 ounces, and took up 16.35 cubic inches. At right, is the G-E Alnico 5 permanent magnet which replaced it. The new magnet weighs just 15 ounces, and occupies only 1.30 cubic inches — a space saving of 87%!

These savings in size and weight result from permanent magnets' inherent volumetric superiority. In addition, permanent magnets provide equally impressive savings in both initial and service costs because of four other inherent advantages.

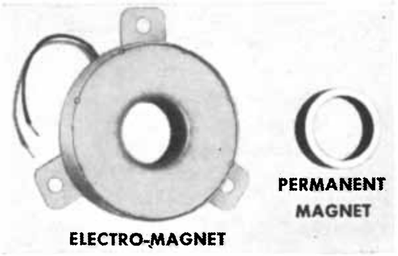

FIGURE 4

First, no power source is required with permanent magnets, because no energy is consumed. Once magnetized, the field is permanently retained.

Second, permanent magnets operate continuously. There can be no interruptions of the field due to power failure.

Third, permanent magnets are extremely stable under changing temperature conditions. They are unaffected by conditions ruinous to electromagnet installations.

Fourth, permanent magnet assemblies are easier to install, and cost nothing to maintain. There are no moving parts to break down, no wiring to burn out, no costly, time-consuming repairs to make.

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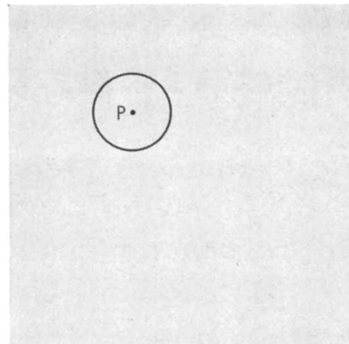

Figure 10

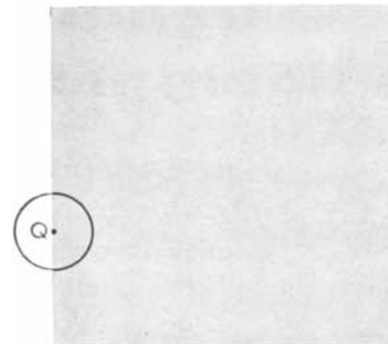

Figure 11

in two points [*Figure* 9]. Since the two points of intersection are a zero-dimensional set by definition, and since any circle surrounding any point of the line must intersect the line, the line is one-dimensional.

To clarify the concept still further, let us apply it to the set of points in a square. If we surround any point inside the square with a small circle, the entire circle will intersect the square [*Figure 10*]. If we surround any point on the boundary of the square with a small circle, then an arc of the circle will intersect the square [*Figure 11*]. Now a circle or any arc of the circle is one-dimensional by the definition of one-dimensional sets of points. Hence the points of the square are said to be a two-dimensional set.

Just to test the definition let us apply it once more to a complex curve—the outline of a four-petaled rose [*Figure 12*]. The most complicated portion of this curve centers on the middle point. If we surround this point with an arbitrarily small circle, the circle will cut the curve in eight points. Since this intersection is a finite set of points, the intersection is zero-dimensional and the curve itself, therefore, one-dimensional.

Some of the principal features of the internal organization of the straight line are now before us. It is to be hoped that they have given some understanding of that structure. This structure provides the answers to other problems involving the straight line. Let us listen once more to Zeno, the master of paradoxes. An arrow in flight, he says, is at any one moment in a definite position and therefore at rest. Hence the flying arrow is at rest wherever it is throughout its flight! With these words Zeno struck at the very concept of motion.

We must agree with Zeno that at any instant of its flight the moving arrow is somewhere in a definite position. And we may, if we like, even agree that the arrow is at rest in each of these positions. How then can the arrow pursue its smooth, continuous course? The structure of the straight line supplies the answer. It tells us that a continuous segment is composed of an infinite number of densely packed points. So continuous motion is no more than an assemblage of densely packed positions of rest. It is like a motion picture with an infinite number of still shots.

Our purpose in this brief survey has been to show that the seemingly simple problem of the nature and structure of the straight line leads to large modern developments in mathematics. These developments may leave readers with the impression that mathematics has gone to fantastic lengths and has distorted the original intuitive concept beyond recognition. Admittedly mathematics is a creation of the mind and its reality is not the reality of the physical world. Yet just these seemingly unrealistic idealizations of mathematics have proved to be the foundation and strength of modern science, as well as of mathematics. More than that, they are the bridge between the world of the senses and any reality that man may come to know.

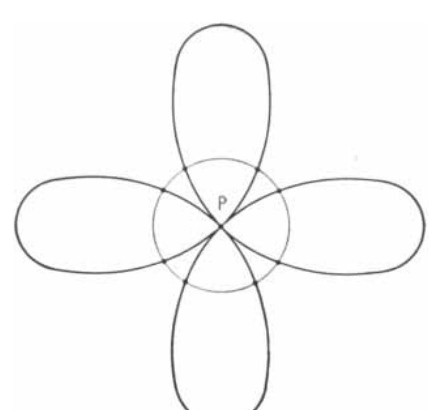

Figure 12

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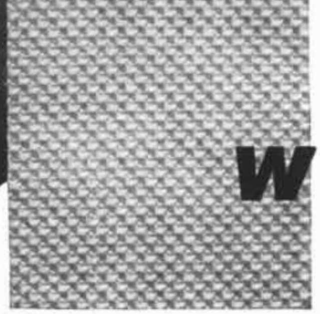

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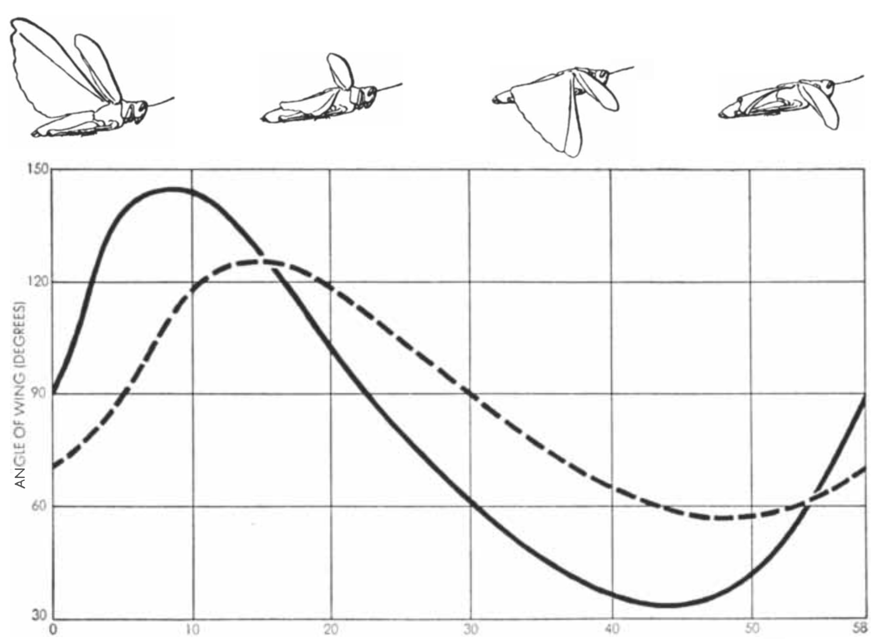
The Flight of Locusts

The tiny forces which a locust exerts in propelling itself through the air have been measured in a series of delicate experiments. The insect's muscle is surprisingly efficient

by Torkel Weis-Fogh

One of the distinguishing traits of the human species is an incurable curiosity about how other creatures manage to do things that we cannot do ourselves. Among nonhuman abilities none is more provocative than the flight of birds and insects. Our own ascent into the air on mechanical wings has not lessened the fascination of this age-old question. How, exactly, do birds and insects fly? In 20th-century terms, we are interested in the aerodynamic details—lift, drag, airfoils and so on. A biologist also has a special curiosity about the power plant. How a flying animal musters enough muscle power to fly, how it controls its flight, how efficiently it uses muscle energy—these are questions of general and fundamental interest on the frontier of biology.

In 1947 the late August Krogh, the Nobel prize-winning physiologist who had been interested in this subject for many years, Martin Jensen and I began an intensive study of insect flight in Krogh's private laboratory near Copenhagen. We wished to investigate the energetics of flapping flight. There is a vast literature on flying animals, but very little quantitative data on how they actually fly. We therefore set up a laboratory wind-tunnel apparatus where we could watch the details of winged flight closely and measure the forces involved.

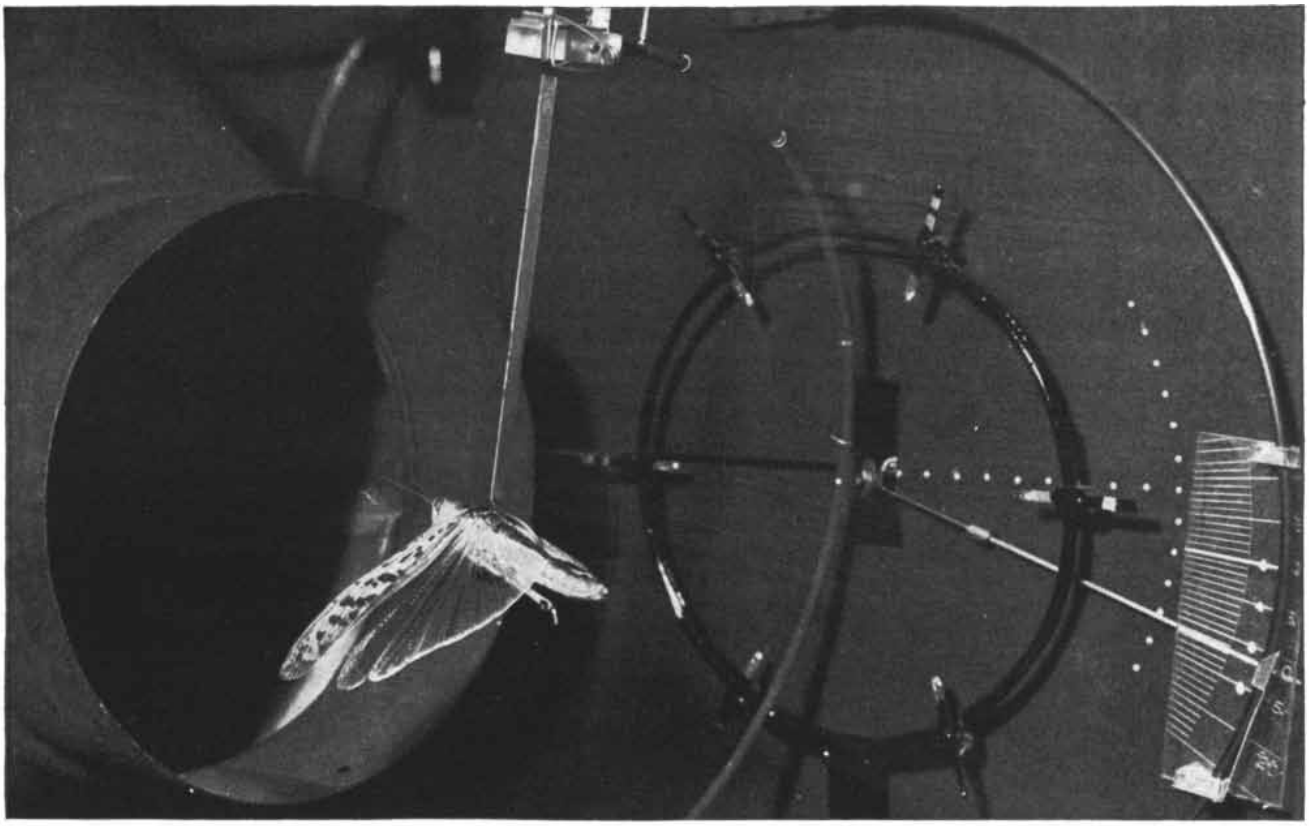


FLAPPING CYCLE of locusts' wings is remarkably constant over a wide range of flying conditions. The broken curve shows the angular up-and-down motion of the forewings; the solid curve, the motion of the hindwings. The angle of each wing at every point is measured between the downward vertical direction and the center line running the length of the wing.

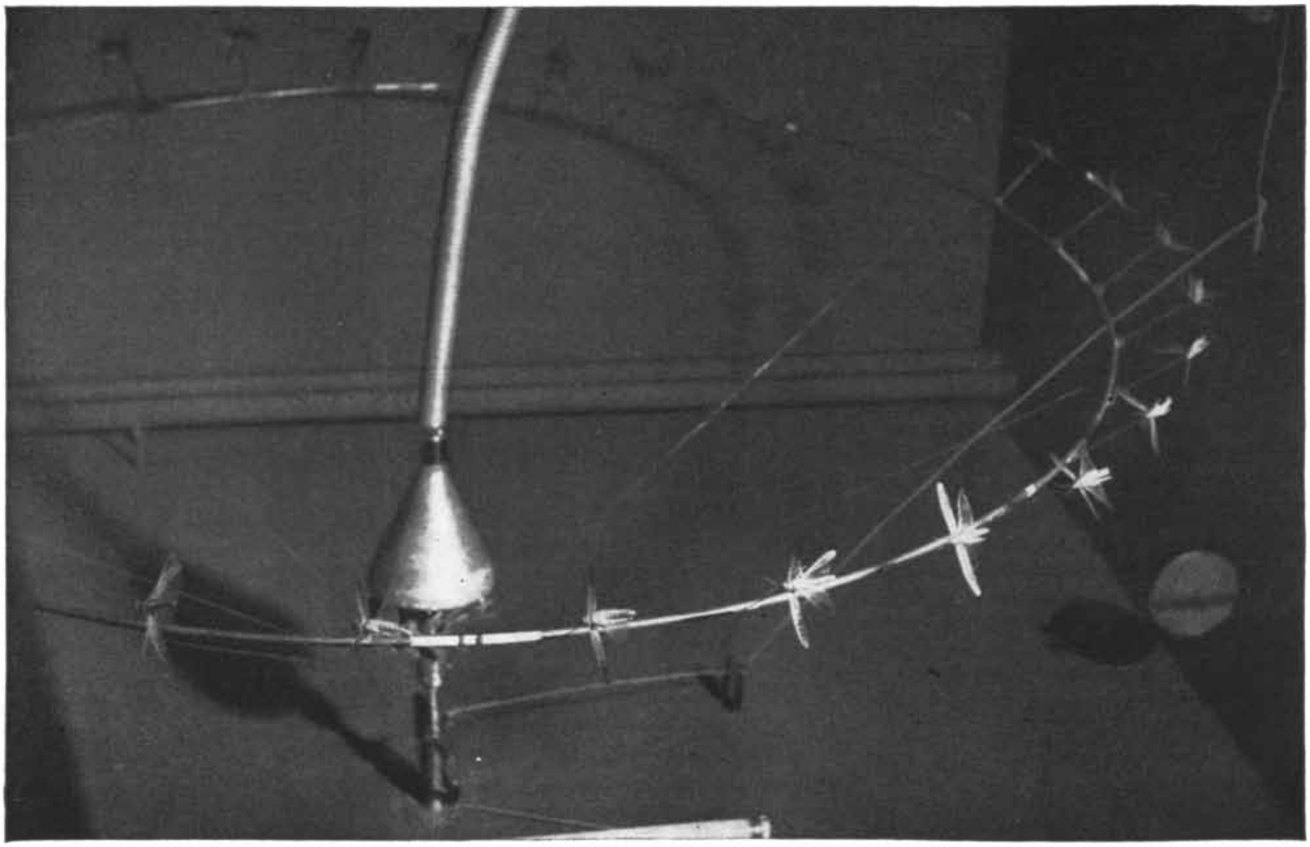
For the experimental animal we chose the big four-winged desert locust (*Schistocerca gregaria*), the celebrated pest which has recently caused great trouble in the Middle East and Africa. This insect was excellent for our purposes because it has an unparalleled ability to maintain steady flight for a long time.

The flapping flight of insects and small birds has some similarities to the flight of an airplane [see "Bird Aerodynamics," by John H. Storer; Scientific American, April, 1952], but the operational differences are quite important. An airplane gets its lift and thrust from the combined action of two separate elements: rotating wings (the propellers) and fixed wings (the airfoils). A bird or insect, on the other hand, merges these functions in the same organ: its wings act both as propellers and as airfoils. The downstroke of the wings produces lift and thrust. On the upstroke the wings must move in such a way as to avoid canceling the lifting force of the downstroke. The pattern of wing motions is highly complex, and this was a focal point of our investigation.

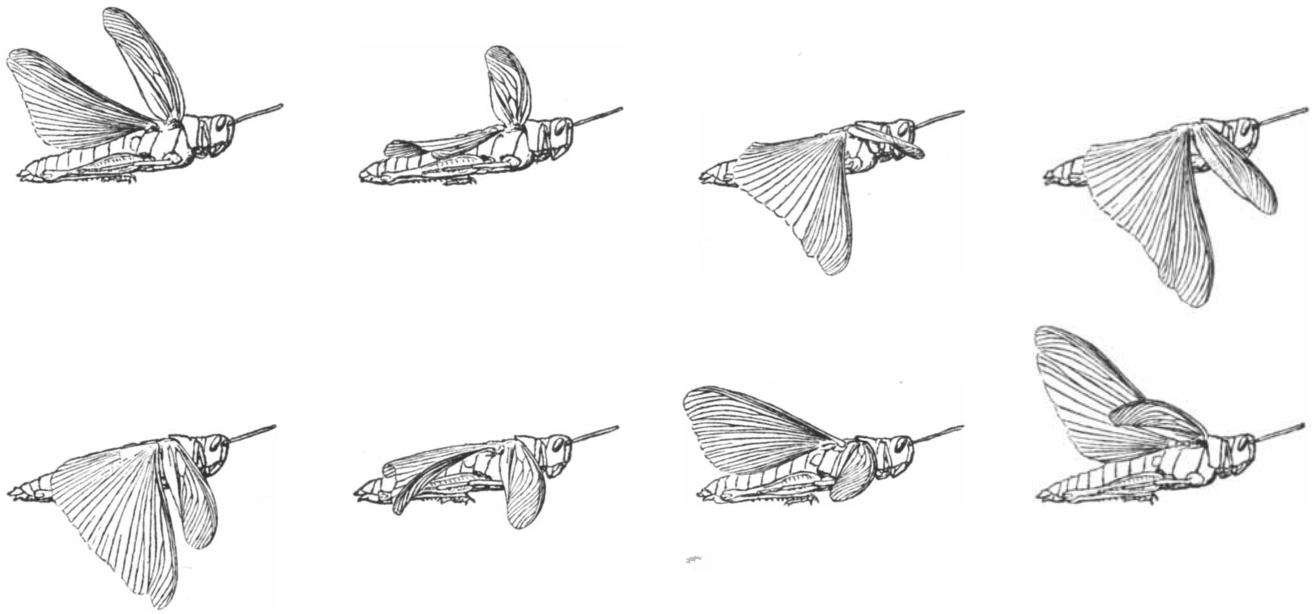
In the experiments a tethered locust was placed in front of the mouth of a blower tube, and it flew against the windstream from the blower [*see cover*]. Its "tether," a slim metal rod attached to its body by a suction cup, allowed the insect free use of its wings, yet held the flying locust in one place in the windstream. It was suspended by this rod from a balance which measured its weight: as the locust flapped its wings, the amount of lift was measured by the reduction of weight on the balance. At the same time a pendulum hanging from the beam of the balance indicated the speed of the insect's flight: when its flying speed was the same as the speed of the air stream (*i.e.*, when its forward



LOCUST IN WIND TUNNEL is suspended from a balance by means of the thin metal rod which passes under its wings and attaches to its body. At left is the mouth of the blower. At right is a scale which shows the insect's angle with respect to the air stream.



LOCUSTS ON MERRY-GO-ROUND flew for hours on end. The purpose of the experiment was to measure the fuel they consumed. This was done by comparing the fat and sugar in their bodies after the flight with the amount of these substances in resting insects.



WING SHAPES must change continually as the locust adjusts to the varying speed and direction of the relative windstream. At the top are shown four positions during the downstroke in normal level flight. At the bottom are four positions during the upstroke.

thrust was equal to the drag of its body), the pendulum hung exactly vertical. Through a feedback servomechanism regulated by the pendulum, the locust controlled the speed of the windstream and thus set its own flying speed.

After studying many flights under these conditions, we were satisfied that the tethered locusts usually flew just about as they do in natural level flight. Their average flying speed was 12 feet per second, about the same as the average speed of a swarm in the field. Most often the insect's lift was equal to its body weight, as in free, level flight.

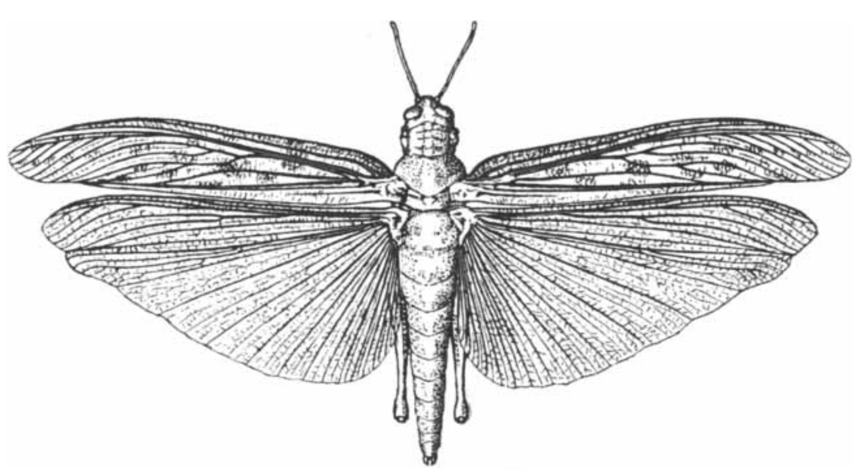
There was, however, considerable variation in the locusts' individual performances. Some loafed along at less than the minimum lift velocity (eight feet per second); some developed greater lift than their body weight and would have risen had they not been held in place by the suspension rod. Yet the remarkable fact was that the wing strokes on all the flights were found to be much the same, whatever the speed or lift. The up and down strokes were always at about the same beat (1,040 cycles per minute), covered the same distance from top to bottom and were inclined at the same angle to the insect's body.

This can mean only one thing: the main variable by which a locust controls its flight is the twisting of its wings. While it keeps the beat uniform, it constantly adjusts the angles of its airfoils to the air by turning the wings. In other words, the wings behave somewhat like a variable-pitch propeller. They "revolve" (flap) at a constant speed and in a fixed orbit, but during each cycle they alter the pitch of their surfaces so as to extract the maximum lift and thrust from the stream of air through which the insect is flying.

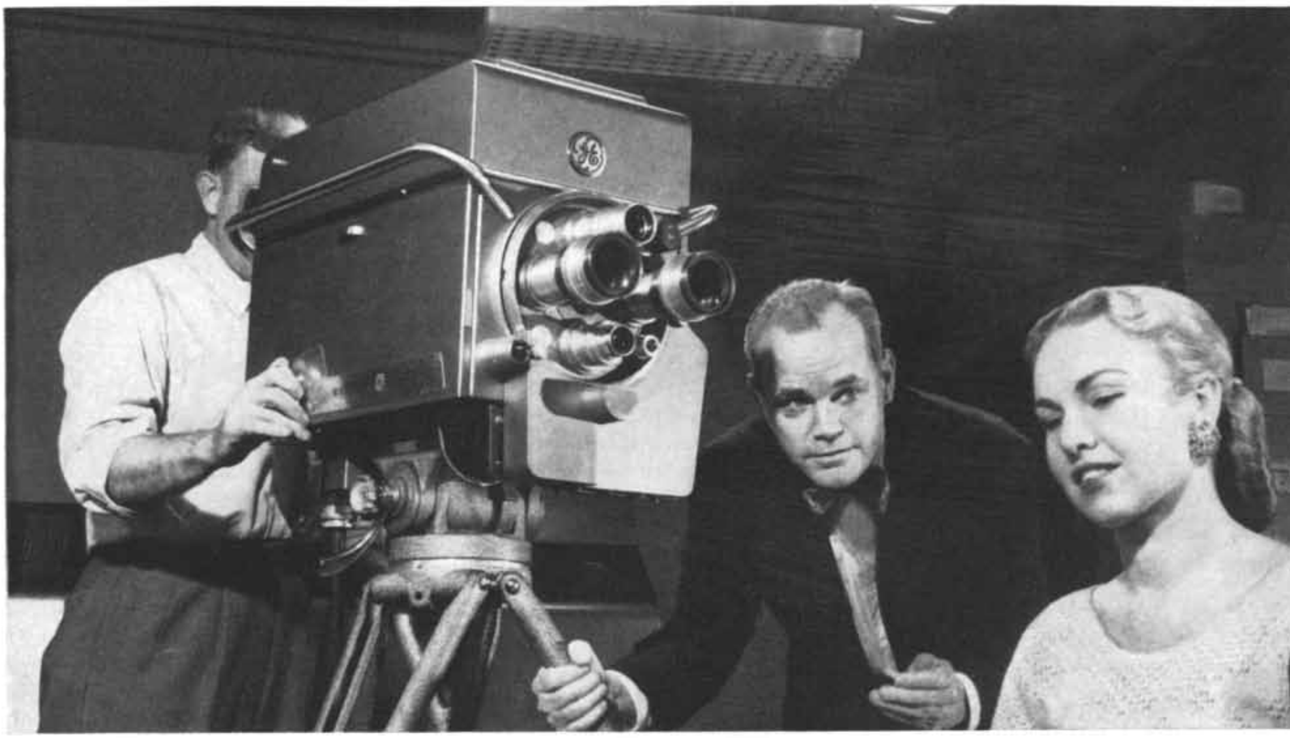
Having found, to our surprise and delight, that the variables were fewer than we had supposed, we were now in a position to calculate the energy a locust must put forth to fly. We could divide the work to be done into three different kinds.

The first is aerodynamic—the work of generating lift and thrust by its wing motions against the air. We made slow-motion pictures of the locust's wing strokes and closely examined the changes in wing angle and shape throughout the cycle [*see drawings above*]. Let us take the forewings first. During the downstroke the leading edge of the wings bends downward. In the second half of the downstroke (when the wings are below the horizontal position), the trailing edge also bends downward, like the flap of an airplane wing. On the upstroke the twist is reversed; now the leading edge bends upward and the flap on the trailing edge straightens out. The twist varies, however, along the wing, being Z-shaped near the insect's body and relatively smooth out at the wing tip, which travels faster through the air.

In the hindwings the leading edge follows much the same cycle as the fore-



TOP VIEW OF LOCUST shows its wings in outline. The forewings are stiff throughout, and their shape is completely under the insect's control. The hindwings are stiff in their forward part, but their rear halves are flexible and their shape is molded by the air stream.



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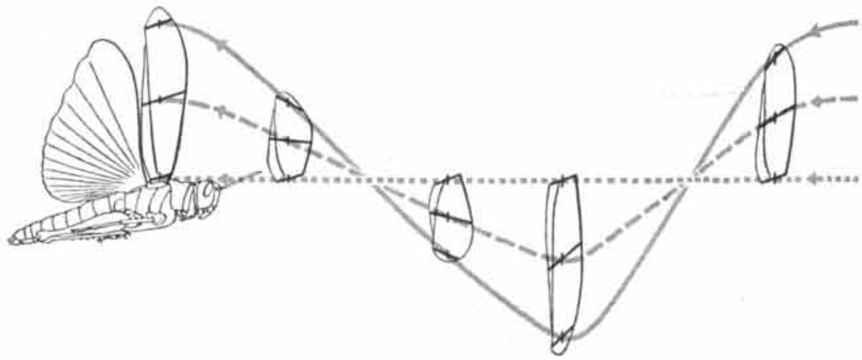


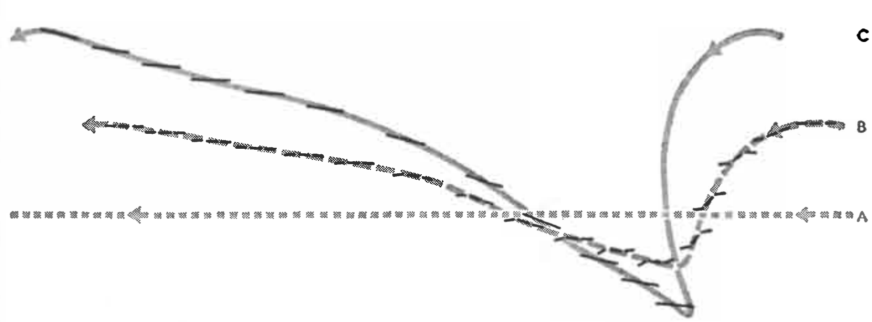
THEORETICAL WING TWIST required to maintain lift throughout a cycle is shown above. The solid curve indicates the relative wind direction against the wing tip; the broken curve indicates the wind against the midwing; the dotted curve, against the base. Straight-line markings on the wings show the angles of their surfaces some points in the cycle.

wings, but the trailing edge is flexible and is molded by the wind flow.

Now all this wing behavior is in accord with well-known aerodynamic principles. Throughout the stroke every part of the wing assumes an effective angle of attack toward the relative wind direction—a small angle which yields forces of lift and thrust. On the downstroke the relative wind is upward, so the wing twists downward to reduce the angle of attack; on the upstroke likewise it turns upward because the wind is downward. On the basis of theoretical considerations we plotted the angles that the wings should take toward the wind throughout the cycle [*see diagram above*], and this schematic pattern was largely confirmed by observations. Martin Jensen worked out the sequence of wing angles in precise detail from an analysis of slow-motion films of actual locust flights [*diagram below*].

Given the various angles of attack during the cycle, our problem now was to calculate how much work the insect had to do to push its wings through the air in generating lift for level flight. To do this it was necessary to compute the force exerted by the wings on the air throughout the cycle. The problem was exceedingly intricate, both because of the continual changes in angle of attack along the wing and because the wing speed varies considerably during the cycle (the upstroke, for example, is much faster than the downstroke).

Jensen went to work on this difficult task. He assumed that the sum of the forces exerted at successive instants during the stroke would give a true basis for computing the work done. The first step was to measure the forces on the wing at different positions in the cycle. For these measurements Jensen used detached locust wings. Exposing them to a controlled windstream, he twisted the wings into the configurations corresponding to successive stages of the stroke, measured the forces of lift and thrust at each position and from these measurements estimated the forces throughout the stroke. These estimates are plotted, for one full cycle, in the chart on page 122. It is an interesting fact, which could not have been pre-



ACTUAL WING TWIST of the forewings of a flying locust was determined from slow-motion pictures. Solid curve shows the wind against the wing tip; broken curve, the wind against the midwing. The short, black line segments indicate the shape and angle of the wing's cross section. The upstroke turns out to be faster than theoretically predicted.

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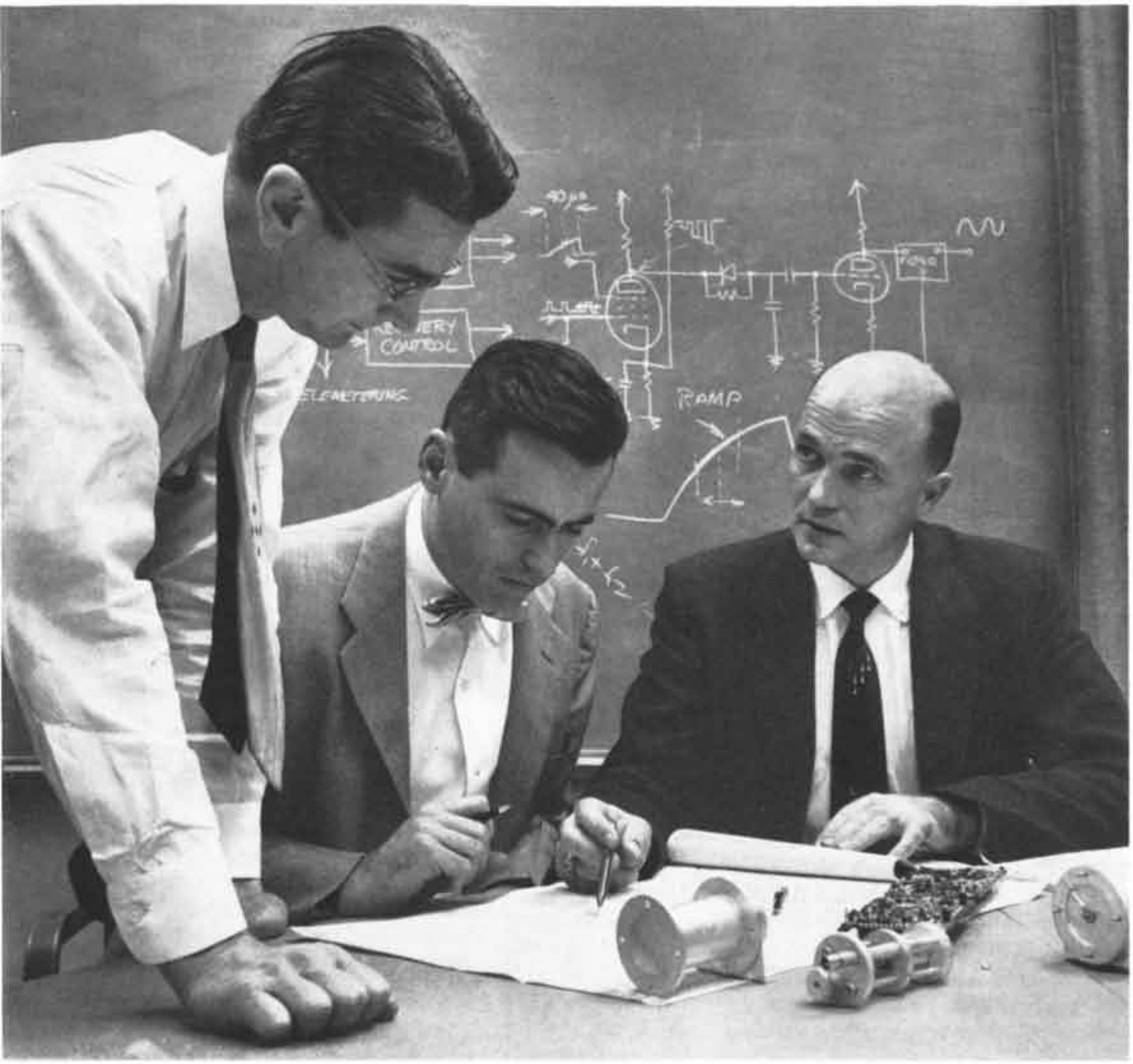

Charles W. Goedecke, Electronic Design Group Engineer, Jay A. Cox, Electronic Research Engineer, and George L. Larse, head of Electronic Systems Development in the Flight Test Electronics Department, discuss important aspects of new electronic command decoding devices for missile guidance systems.

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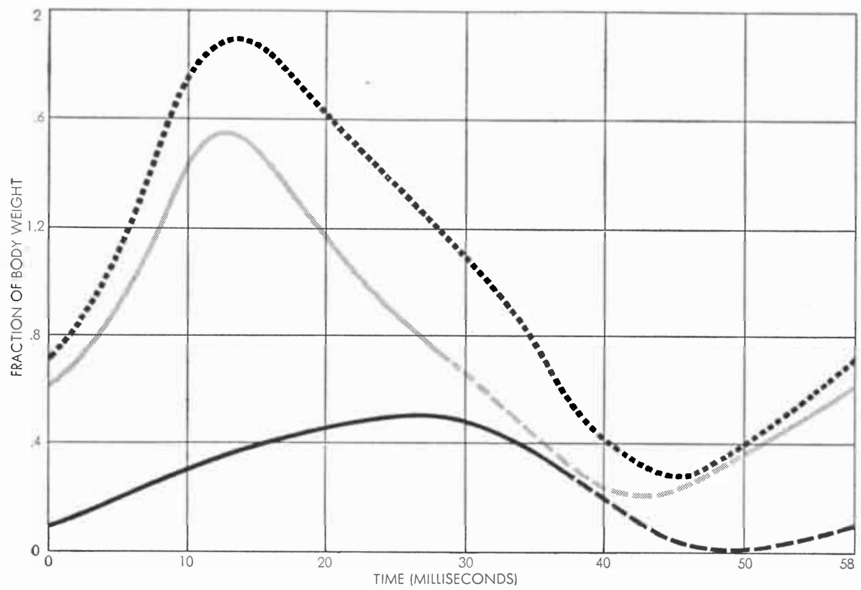


FORCES PRODUCED over the course of an average wing beat are summarized in this graph. The lower curve gives the contribution of the forewings; the middle curve, the contribution of the hindwings. Solid sections represent the downstroke; broken sections, the upstroke. Dotted curve at the top gives the total lift. About 70 per cent comes from the hindwings.

dicted by theory, that the hindwings produce about 70 per cent of the total force.

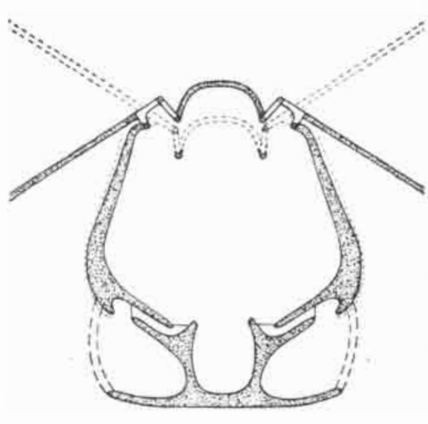
After a couple of months of intense calculation, Jensen reduced his set of estimates of instantaneous forces to an average, estimating the forces of lift and thrust generated by the stroke as a whole. These figures proved to be very close to the actual lift and thrust developed by locusts flying in the wind tunnel, as measured by our instruments.

Thus we had a secure basis for estimating the aerodynamic work done by the locust. Jensen's plot of the variations in wind forces during the stroke gave us the information we needed for calculating the amount of this work.

We now turned to a second factor in the equation. When the locust moves its wings, it must spend energy not only to drive them against the resisting air but also to overcome the inertia of their mass. That is to say, work must be done to accelerate or decelerate the wing mass itself. During the locust's wing-flapping cycle it must stop its wings at the top and bottom of the stroke and accelerate them in the course of the stroke. Knowing the weight of the wings and their velocity at various stages of the stroke, we could calculate the work done against inertia.

Finally, we had to consider still another resisting force against which the locust must work in moving its wings. The wings are hinged to its body in such a way that the body changes shape when the wings flap. The body walls are elastic but rather stiff. Thus they act as a kind of spring which opposes the wing movements. We were able to estimate their opposing force in various positions of the wing stroke by removing the muscles and measuring the elastic pull of the walls on the wings by means of gauges.

Now we could proceed to estimate the total work done by a flying locust by combining the three quantities—aerodynamic, inertial and elastic [*charts on next page*]. The calculation showed that in level flight a locust uses 13.7 calories of energy per gram of body weight per hour. One calorie of energy is equivalent



ATTACHMENT OF WINGS is diagrammed schematically. The view is a cross section through the insect. Each wing is a lever, pivoted at the top of the side wall of the body and fastened to the top, or back, wall. In flapping its wings the locust must use force to change the shape of its body walls.

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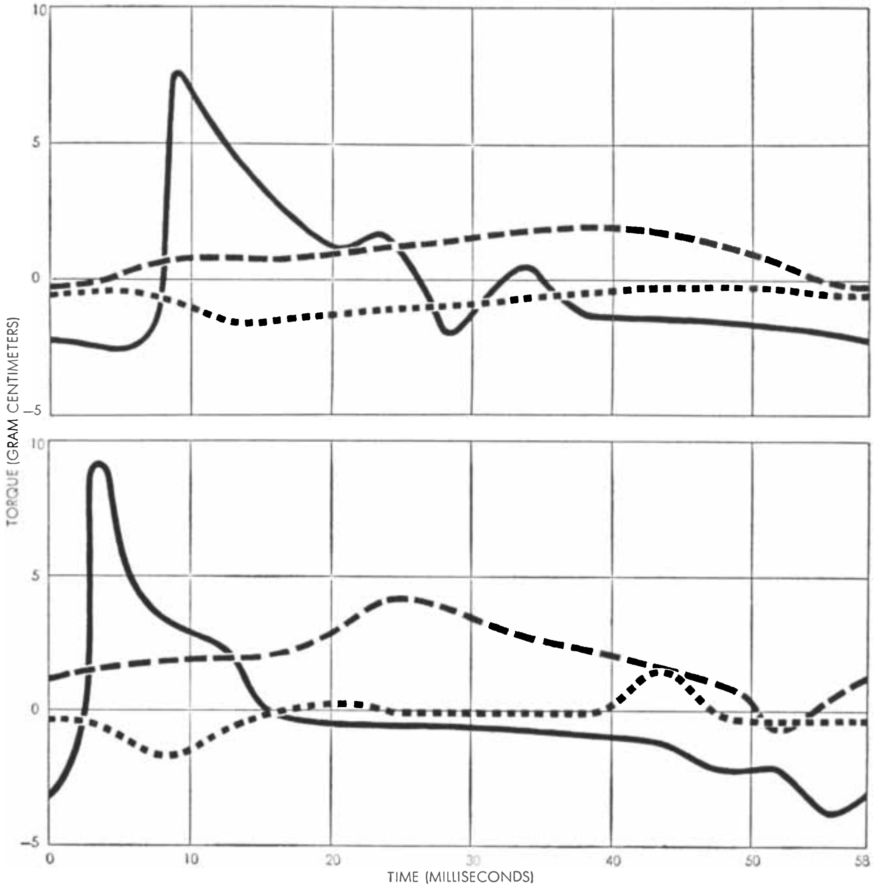
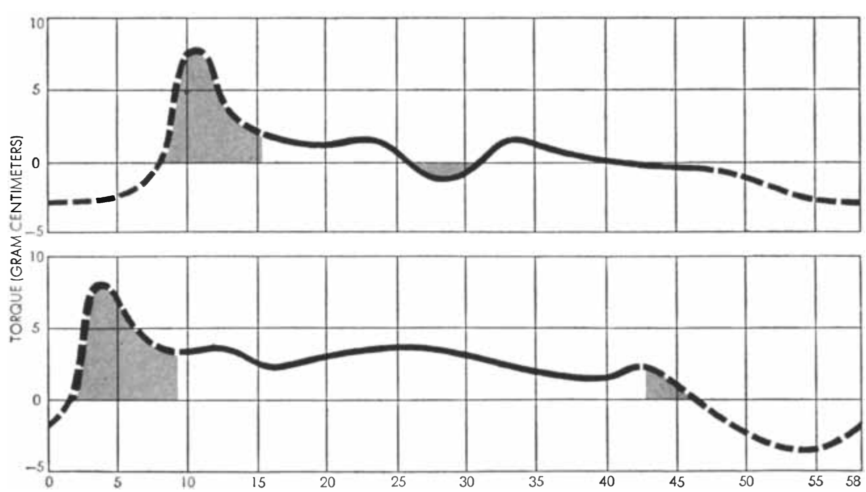


TURNING FORCE, or torque, must be produced by the locust's muscles to provide the aerodynamic forces of lift and thrust (*broken curves*), to overcome wing inertia (*solid curves*) and to change the shape of the insect's elastic body (*dotted curves*). The upper graph shows the forces developed in the forewings; lower graph, the forces in the hindwings. A positive torque tends to move the wings downward; a negative torque, upward.



TOTAL TURNING FORCE required from the muscles is obtained by adding the curves in the graph at the top of the page. Upper curve gives forewing torque; lower curve, hindwing torque. Solid sections indicate downstroke; broken sections, upstroke. The shaded areas show the portions of the flapping cycle during which the muscles are doing negative work.

to the work of raising a three-pound weight about one foot. Thus in an hour's flying a two-gram locust expends enough energy to raise a three-pound weight to a height of more than 27 feet!

One might think that it should now be simple to compute the efficiency with which a locust uses its available muscular energy. By adding up its different forms of energy production or by measuring its rate of metabolism we can estimate that on the average a flying locust produces a total of about 70 calories of energy per gram of body weight per hour. Part of this energy goes into mechanical work, part into body heat and part into evaporating water. However, we cannot determine the muscles' mechanical efficiency simply by calculating the ratio of the work done to the total energy produced. The difficulty is that in flapping its wings a locust does two kinds of work—positive and negative—and the efficiencies in the two kinds differ.

Negative work here means mainly the work done in slowing down the wings at the end of the upstroke or downstroke before they start in the opposite direction. This work is so considerable that the total inertial work may be greater than the aerodynamic work of producing lift. However, the inertial work is not so large a drain on the locust's energy as the aerodynamic, partly because negative work is less expensive than positive work; it is performed at a lower cost to metabolism. Human muscle, according to some studies, needs only about one fourth as much energy production for negative work as for positive work; that is, it is about four times as efficient in negative work.

Of the total power a locust uses in flying—13.7 calories per gram per hour—8.9 calories goes into positive work and 4.8 calories into negative. If the relative efficiencies for the two kinds of work are the same as in human muscle, the overall efficiency of a locust's flight muscles is about 14 per cent. If negative work is as expensive as positive work, then the locust's muscle efficiency is 20 per cent.

Either figure is astonishing. Some estimates have put the muscular efficiency of flying insects as low as 2 per cent. It appears now that the mechanical efficiency of the locust's muscles is as great as that of human leg muscles, although the insect's rate of metabolism is 10 to 20 times faster than man's. In other words, the muscles of a flying insect perform about 10 to 20 times more work, in proportion to size, than those of a human being working at top speed.

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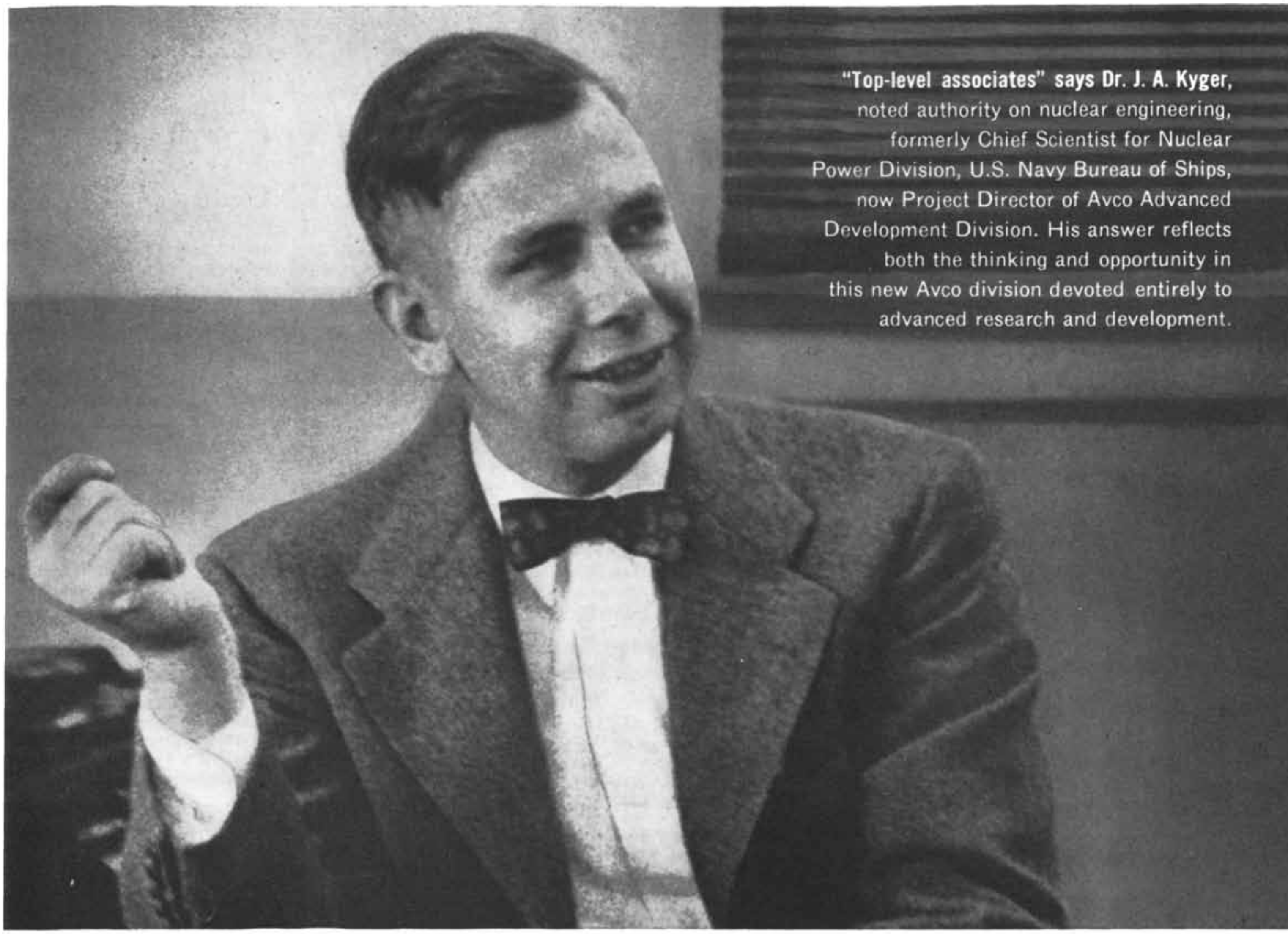

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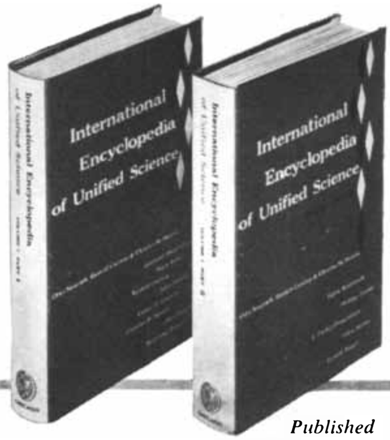

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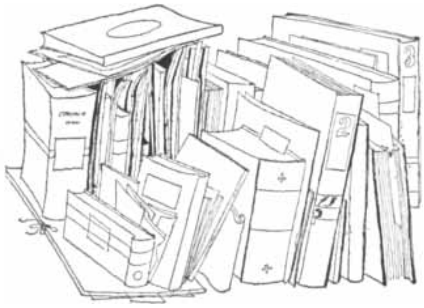

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by Harrison Brown

EARTH IN UPHEAVAL, by Immanuel Velikovsky. Doubleday & Company, Inc. ($3.95).

The third in the series of Immanuel Velikovsky's unconventional reinterpretations of earth history has now been published, and it is not necessary to read many pages to find that it is as generously packed with nonsense as were its predecessors. Ordinarily a book so obviously ridiculous as this would merit no notice, except perhaps to be cited as an outstanding example of what the scientific attitude is *not*. But the widespread publicity that attended the publication of the first of these books, *Worlds in Collision*, in 1950, has caused Velikovsky's theories to receive considerable attention in both scientific and nonscientific circles. Emotions have run high; the scientists have said that Velikovsky is crazy; the publishers have said that the scientists are intolerant; Velikovsky has written statements implying that he is a martyred genius; the public-at-large is confused—or at least should be. Indeed, the case of Velikovsky, his theories, his critics, his publishers and his public is an outstanding case of lack of communication between scientists and nonscientists. It illustrates dramatically the extent to which intelligent and otherwise highly educated nonscientists may fail to understand the scientific method and scientific discipline. For these reasons it is perhaps worthwhile to examine the Velikovsky case once again.

In *Worlds in Collision* Velikovsky attempted to correlate various accounts of happenings in ancient writings and folklore in terms of a single physical theory. He concluded that a comet originating from the planet Jupiter passed near the earth about 1500 B.C. and again about 1450 B.C. During its travels the comet stopped the earth's rotation for a time and precipitated various phenomena recorded in legend, such as the "raining of blood," the "hail of stones," the "raining of naphtha" and the "fall of manna," together with a startling variety of other events and catastrophes. Electrical discharges between the earth and other planets caused the earth's magnetic poles to change. Planets exchanged orbits. The comet finally ended its messy spree and became the planet Venus.

Velikovsky followed this with a second book in 1952, *Ages in Chaos*, which was a reconstruction of history from the Exodus to the Egyptian king Akhnaton. Now in the third volume, *Earth in Upheaval*, he attempts to marshal the geological evidence for his general theory. He sees in practically every geological event a confirmation of his views. He discusses mountain formation, age-dating, vertebrate paleontology, petroleum geology, meteorite craters and numerous other topics. He quotes some data which we know to be true, some which we know to be dubious and some which we know to be false. He quotes interpretations of facts which are correct and interpretations of facts which are wrong—and impartially he gives equal weight to each. He concludes that "whenever we investigate the geological and paleontological records of this earth we find signs of catastrophes and upheavals old and recent." And somehow this mass of information and misinformation is supposed to show that two great series of catastrophes have taken place in historic times, the first in the 15th century B.C. and the other (of lesser intensity) in the eighth century.

The launching of the Velikovsky theory was fully as remarkable as the theory itself. It was first brought to public attention by the late John J. O'Neill, science editor of the New York *Herald Tribune*. Sensational articles about the theory subsequently appeared in *Harper's*, *Collier's* and *The Reader's Digest*. By the time competent scientists were given the opportunity of evaluating the theory, it had been widely discussed and praised by a variety of nonscientists, including Fulton Oursler, Clifton Fadiman and Harold L. Ickes.

When evaluating a new theory, a scientist attempts to divorce himself from prejudice and to test the various facets of the theory against the facts in his possession. He asks himself: "What does the theory explain? What is left unexplained? Does the theory contradict reputable observations?" In the anti-authoritarian, individualistic world of science each person must sift through a theory and see for himself whether or not it fits the facts.

When I first read *Worlds in Collision* I, like many of my colleagues, put Velikovsky's theory to the foregoing tests. I made an itemized list of contradictions and errors. The list quickly grew to unwieldy proportions, and it became amply clear that the theory was nonsense. I stated this emphatically in a published review. Quite independently numerous scientists reached the same conclusion. The unanimity of scientists led nonscientists to suspect a conspiracy. Scientists were accused of being "prejudiced," "blinded by orthodoxy," "dogmatic."

Several scientists, notably Cecilia Payne-Gaposchkin of the Harvard Observatory, carefully pulled Velikovsky's statements to pieces, point by point. The scientific critics were prejudiced, orthodox and dogmatic only to the extent of insisting that important facts not be ignored or distorted. To this day I have not seen a single defense of Velikovsky's theory by a competent scientist. All the defenses of Velikovsky's views that have come to my attention have been written by nonscientists unfamiliar with the facts. Many of the defenders appear to believe that scientific arguments can be won with rhetoric or by taking a public opinion poll and assessing how many persons are "for" and how many are "against" the theory.

We conclude with an unusually high degree of safety that Velikovsky's theories are pseudoscientific nonsense. In the light of this, let us now examine some of the developments which followed the publication of *Worlds in Collision*.

In the world of science the individual research worker usually subjects his results and theories to his fellow scientists for searching criticism and checking before making his results known to the public. If he is at a university he first solicits the criticisms of his local colleagues, following which he shows his results to scientists in other institutions. When he has thus satisfied himself that his results or ideas make sense, he submits a paper to a scientific journal. The paper is sent to anonymous referees for criticism, and if they judge it worth publishing it is published in that journal.

The strong feelings expressed by scientists following the publication of *Worlds in Collision* stemmed in large part from the fact that an inordinate amount of publicity and a surprising amount of credence had been given to the theory by magazines, newspapers and the book's publishers without any attempt being made to ask whether or not the theory made sense. The discipline normally imposed by scientists upon themselves had been bypassed.

The Macmillan Company, whose trade book division published *Worlds in Collision*, is of course a highly reputable publishing house. Its technical and textbook division usually is extremely careful in its choice and editing of scientific treatises. Apparently in this case the technical-book division didn't know what the trade-book division was up to. Some scientists who were particularly peeved about Velikovsky's theories wrote to Macmillan and implied strongly that *Worlds in Collision* reflected rather badly upon the technical judgment of the publishing house. The Macmillan Company naturally became concerned, for scientists account for a substantial fraction of technical-book purchases and in addition they comprise a good proportion of technical-book authors. The net result was that Macmillan decided to discontinue publication of *Worlds in Collision*. Doubleday & Company, which does not publish scientific textbooks, took over the publication of the book and Velikovsky's subsequent works.

The incident between the scientists and the publishers caused *Newsweek* to comment: "One of the most cherished rights of the nation's teaching profession is academic freedom, . . . yet a small group of professors themselves stood accused of a major assault on academic freedom." The words of the newspaper columnist George E. Sokolsky were even harsher: "Of course, what the learned and liberal professors wanted was the total suppression of a book which opposes their dogma. Scientists tend to become dogmatic like theologians, whom they denounce as dogmatic."

Velikovsky wrote in the foreword to *Ages in Chaos:* "Should I have heeded the abuse with which a group of scientists condemned *Worlds in Collision* and its author? Unable to prove the book or any part of it wrong or any quoted document spurious, the members of that group indulged in outbursts of unscientific fury. . . . The guardians of dogma were, and still are, alert to stamp out the new teaching by exorcism and not by argument, degrading the learned guild in the eyes of the broad public, which does not believe that censorship and suppression are necessary to defend the truth."

Velikovsky apparently looks upon himself as an original thinker whose truths so contradict "orthodox" scientific thought that the members of the scientific community are taking every possible measure to keep the new heretical ideas from spreading. The scientists, he believes, have organized themselves into a sort of anti-Velikovsky club which is extremely powerful and which cajoles or threatens all persons who look favorably upon Velikovsky's theories. They "thus drove many members of academic faculties into clandestine reading of *Worlds in Collision* and correspondence with its author," he says.

Velikovsky is a master of implication and innuendo. He is able to mention the names of certain scientists in such a way that at first reading readers are led to believe that the scientists mentioned agree generally with his conclusions. He even attempts to make the reader believe that an unmitigating critic such as Mrs. Payne-Gaposchkin is conceding points to him.

Perhaps the most flagrant use of innuendo is revealed in the "Acknowledgments" section of *Earth in Upheaval*. Here Velikovsky implies strongly that Albert Einstein was beginning to understand Velikovsky's views and that the two men were close to agreement: "The late Dr. Albert Einstein during the last eighteen months of his life (November, 1953–April, 1955), gave me much of his time and thought. . . . We started at opposite points; the area of disagreement, as reflected in our correspondence grew ever smaller, and though at his death (our last meeting was nine days before his passing) there remained clearly defined points of disagreement, his stand then demonstrated the evolution of his opinion in the space of eighteen months."

This carefully worded statement, upon close analysis, clearly says nothing definite or significant—but it creates an impression upon the casual reader.

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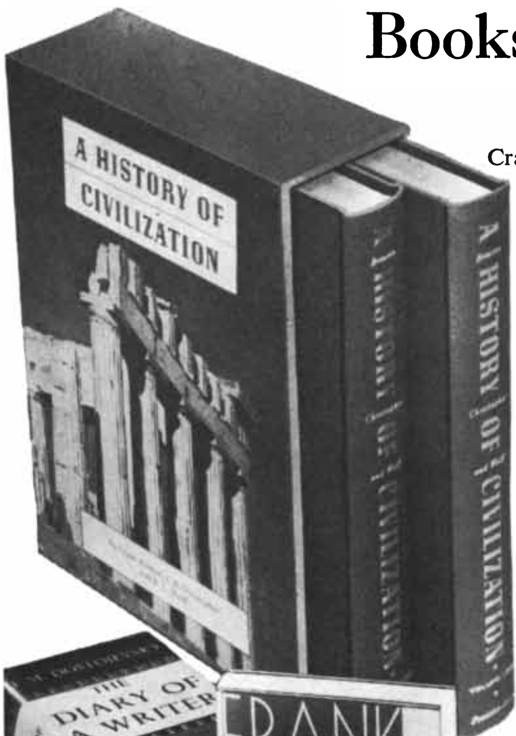

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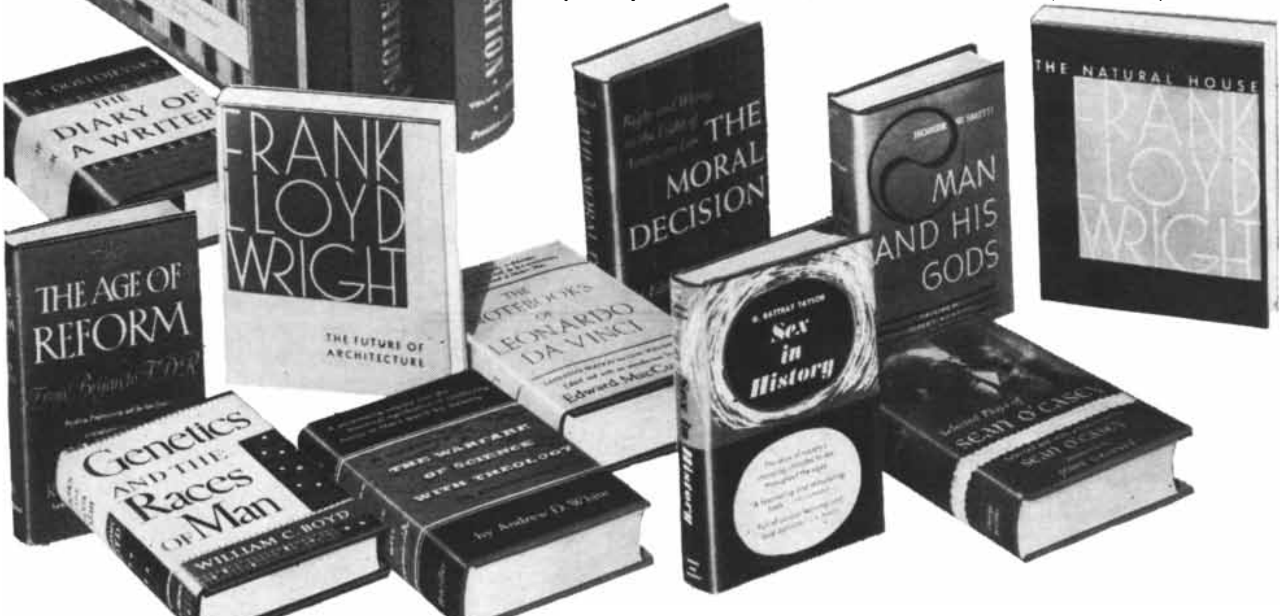

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ly inquiry, Velikovsky is clearly such a man. He, like most of us, wonders about the how and the why of our universe. Even though his conclusions may be as wrong as wrong can be, it is certainly not wrong for him to publish his theories and his viewpoints—provided, of course, that he is willing to subject himself to ruthless criticism.

It seems to me that the major culprits in the Velikovsky affair are the publishers—not because they publish Velikovsky's books but because of the way in which they publicize the books. They pretend first of all that *Worlds in Collision* precipitated a major scientific controversy. On the jacket of *Ages in Chaos* they state: "As the most controversial book in many decades, it was the subject of more than 3000 reviews, and defenders and opponents debated it with such fervor as is reserved only for books that lay bare new fundamentals."

Who were the defenders in this debate? Doubleday & Company has kindly given us as an appendix to *Ages in Chaos* a number of excerpts from favorable reviews. The staunch defenders include anonymous editorial writers of the New York *Sunday News*, *The Saturday Evening Post*, *Collier's*, *Everybody's Digest*, *Newsweek*, *Pathfinder* and *The American Mercury*. A number of literary critics are listed as endorsing the book. But a scientific controversy implies that scientists argue with scientists, not that scientists argue with editorial writers, literary critics and copy writers for book-jacket blurbs.

On the jacket of *Earth in Upheaval* the publishers write: "Dr. Immanuel Velikovsky's monumental first work . . . created a furor of controversy unknown since Darwin's debate ninety years earlier." And they conclude: "Here is evidence, assembled from mountains and oceans, deserts and tundras, polar regions and jungles, to establish the Velikovsky theory as one of unshakable solidity. . . . With the numerous facts assembled in this book the great controversy between Velikovsky and his opponents turns clearly in his favor."

When the hucksters attempt to sell scientific theories as they hawk canned goods, automobiles and cigarettes, a scientist boils. And his boiling point is reached even more quickly when he realizes that the hucksters in this case don't have the fuzziest understanding of what they are attempting to sell.

Each of us probably has his own views concerning the ethical principles involved in the Velikovsky affair. I offer mine for what they are worth.

First, I believe that Velikovsky had

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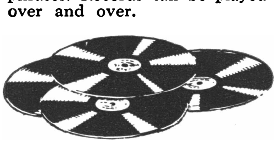

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every right to write his book, and indeed he was morally obligated to bring his theories to the attention of other scholars.

Second, I believe that the Macmillan Company had every right to publish *Worlds in Collision*, although the company would have profited greatly from some trustworthy scientific refereeing in valuating the book.

Third, I believe that pressures which were brought to bear upon the Macmillan Company by some scientists were unfortunate. Complaints and criticisms were very much in order, but threats even by innuendo should not have been made.

Fourth, I believe that periodicals such as *Harper's*, *Collier's* and *The Reader's Digest* erred in pushing a scientific theory without obtaining adequate scientific counsel.

Fifth, I believe that literary critics who review books pertaining to science should know something about science.

Sixth, I believe that Velikovsky has behaved badly in that he has not really answered his critics in a way that befits a true scholar. He has relied far too heavily upon selected data, upon innuendo, upon rhetoric.

Seventh, I believe that the persons who write advertisements which are designed to sell Velikovsky's books are the worst offenders in the entire affair. Five years ago I wrote that in 10 years Velikovsky's book would be forgotten. Although I still hope that this will be true, the power of the huckster is such that I doubt it. Where there are dollars to be made, there will always be persons volunteering services.

Short Reviews

MAMMALS OF THE WORLD, by François Bourlière. Alfred A. Knopf ($12.50). LIVING MAMMALS OF THE WORLD, by Ivan T. Sanderson. Hanover House ($9.95). Both of these attractive, large-format monographs present popular, illustrated surveys of the world's mammals from the monotremes to the ungulates. Bourlière's book, a companion to his *The Natural History of Mammals*, is arranged by natural habitats. A final chapter deals with the adaptation of mammals to aerial and aquatic life. The text is too crowded with facts and too hurried to be entertaining, but the pictures, many in color, are with few exceptions first-rate. With the help of the electronic flash, powerful telephoto lenses, superfast film and other modern tools of photography, the author has caught the animals in their natural pos-

tures and settings. The Sanderson volume is more conventional but has its own special merit. Following the usual scheme of zoological classification, the author provides for each mammal a brief, ably written sketch which describes appearance, habitat, life and habit. He adds illuminating and amusing sidelights. The story that lemmings "patter to their doom . . . by casting themselves *en masse* into the heaving Atlantic Ocean" is "almost complete rubbish." Spiny dormice drink palm mimbo, a semifermented beer which drips from the head of certain palms and "intoxicates even goats." Pigs lead "the most orderly and cleanly of lives," unless degraded by man, and have an I.Q. second only to that of the great apes. The brown rat, being the "finest—in every sense of that word and especially in efficiency—product that Nature has managed to create on this planet to date," will very likely inherit the earth by surviving even if men should succeed in exterminating themselves by profligate radioactivity. The 330 illustrations in this book, though mostly captivity shots, attain a pretty high average in quality, and some of the color photos (of which there are 190) are superb.

SEEING AMERICA'S WILDLIFE IN OUR NATIONAL REFUGES, by Devereux Butcher. The Devin-Adair Company ($5.00). At the rate man is killing wild animals—except for such canny types as rats—there would soon be none left were it not for the fact that a few farsighted and less bloodthirsty men have established game refuges. This book makes a photographic tour of the U. S. sanctuaries and refuges, describes them and their inhabitants and tells of the value and problems of conservation. Among the places visited are Aransas on the Blackjack Peninsula of Texas, famous for its tiny tribe of whooping cranes; the duck hospital at Bear River, Utah, which saves the lives of thousands of waterfowl stricken with botulism; the Chincoteague Island refuge off Maryland, an important way station for several lanes of waterfowl traffic; the Nevada and Arizona game ranges, where the bighorn ("avidly sought by gunners") survives; Hart Mountain in Oregon, affording protection to the swift and graceful pronghorn antelope, the mule deer and the vanishing sage hen; Laguna Atascosa and Santa Anna in Texas, the habitat of many kinds of birds not to be seen anywhere else in the U. S.; Bogoslof Island in the Aleutians, where sea lions can bully their wives in peace; Okefenokee in southeastern Georgia, which protects a unique cypress swamp together with its bobcats, minks, owls and alligators; Pelican Island on Florida's east coast, the first of our federal refuges, created by Theodore Roosevelt in 1903; Condor Refuge in California, an almost inaccessible mountain area where the largest of all North American birds is preserved. A readable, well-illustrated volume, persuasively arguing an admirable cause.

THE NATURAL HISTORY OF NORTH AMERICAN AMPHIBIANS AND REPTILES, by James A. Oliver. D. Van Nostrand Company, Inc. ($6.95). THE REPTILE WORLD, by Clifford H. Pope. Alfred A. Knopf ($7.50). Dr. Oliver's book discusses the folklore of toads, turtles, crocodiles, snakes and other animals; their economic value, their movements, food, growth, size and longevity. He writes clearly and simply, and is master of all aspects of his subject, as one would expect of the Curator of Reptiles of the New York Zoological Society. The book is mainly illustrated by drawings, which are average, but a few of the plates deserve notice—in particular a photograph of two male red diamond rattlesnakes addressing each other in a combat dance. Pope's book is more informal and covers a wider range of species. The account is by families and provides a good deal more information than is usually found in popular natural histories. The illustrations consist of a truly superb collection of 221 photographs. Incidental gleanings from Oliver and Pope: Toads do not produce warts. Neither turtles nor alligators live to be as old as Methuselah (150 years is the record for turtles, 56 for alligators). Hoop snakes don't roll about like hoops. Snake charmers can't charm cobras by playing the flute because cobras can't hear (the reason they wiggle rhythmically is that they imitate the snake charmer). Rattlers don't always oblige by rattling before they strike. Whiskey, alas, is no good for snakebite.

WILD AMERICA, by Roger Tory Peterson and James Fisher. Houghton Mifflin Company ($5.00). Two well-known naturalists, each of whom specializes in birds and has written many books about them, teamed up in the spring of 1953 and made a 100-day, 30,000-mile tour of the perimeter of the North American continent by station wagon, boat and airplane. Fisher, who is British, had never visited the U. S., and Peterson enjoyed the opportunity of introducing his colleague to cities, motels, superhighways, Coca-Cola dispensers, as well as to alligators, goose tundra,

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Hicksville, Long Island, N. Y.

bison, the Everglades, sequoias, the Grand Canyon, limpkins, long-billed curlews and countless other beauties of wildlife and wilderness. It was an exciting, marvelously varied odyssey.

THE BIRDS OF THE BRITISH ISLES: VOLS. III AND IV, by David Armitage Bannerman, with illustrations by George E. Lodge. Oliver and Boyd (45 shillings each). These excellent volumes continue a work begun several years ago, the first two installments of which were reviewed in SCIENTIFIC AMERICAN in April, 1955. Volume III completes the account of the passerine birds, from chiffchaff and black chat to whinchat and water-ouzel. Volume IV begins the survey of the nonperching birds: swifts, nightjars, bee eaters, hoopoes, woodpeckers, cuckoos and so on. Dr. Bannerman writes attractively, and Lodge's color plates are gentle, frequently lovely.

CALIFORNIA GRIZZLY, by Tracy I. Storer and Lloyd P. Tevis, Jr. University of California Press ($7.50). A melancholy memorial to an extinct species. The California grizzly, once numerous (about 10,000 specimens) and dominant in that state, was exterminated about 30 years ago. This book describes the animal's physical appearance and habits, its relations to the Indians and Spaniards, bear-and-bull fights and grizzly hunting. It tells some stories of famous captive grizzlies. Photographs, paintings, bibliography.

ATOMIC POWER; AUTOMATIC CONTROL; A TWENTIETH CENTURY BESTIARY; THE NEW ASTRONOMY; THE PHYSICS AND CHEMISTRY OF LIFE: by the Editors of *Scientific American*. Simon and Schuster ($1.00 each). Ninety of the articles that have appeared in this magazine since 1948 are here assembled by topics and published in five paper-backed volumes. The original illustrations are not included, but there are drawings, bibliographies and notes on the authors of the articles.

MR. GOULD'S TROPICAL BIRDS, edited by Eva Mannering. Crown Publishers ($7.50). This is a selection of 24 plates taken from the superb bird folios of John Gould, originally published in the 19th century. Gould was an incredibly productive ornithological artist and publisher. When he died in 1881, he had produced 41 large folio volumes containing 2,999 hand-colored plates, and had earned a fortune from his labors. His plates have neither the marvelous delicacy nor the lifelike grace of Audubon's and have occasionally been excelled by certain other bird painters. Yet altogether the quality of Gould's work is very high, and some of the reproductions in this volume printed in Germany are second to none in richness of color and artistic composition.

FAMOUS PROBLEMS AND OTHER MONOGRAPHS, by F. Klein, W. F. Sheppard, P. A. Macmahon and L. J. Mordell. Chelsea Publishing Company ($3.25). As in a companion volume, *Squaring the Circle, and Other Monographs*, reviewed here two years ago, the publishers have assembled in a single volume several short books of interest to a fairly wide circle of mathematicians and students. Felix Klein is represented by his "Famous Problems of Elementary Geometry," which discusses the duplication of the cube, the trisection of an angle, the squaring of the circle. The Sheppard monograph is an introduction to the tensor calculus. Major Macmahon's study is an elementary treatment of combinatory analysis. Mordell's three lectures deal with the celebrated "Last Theorem" of Fermat.

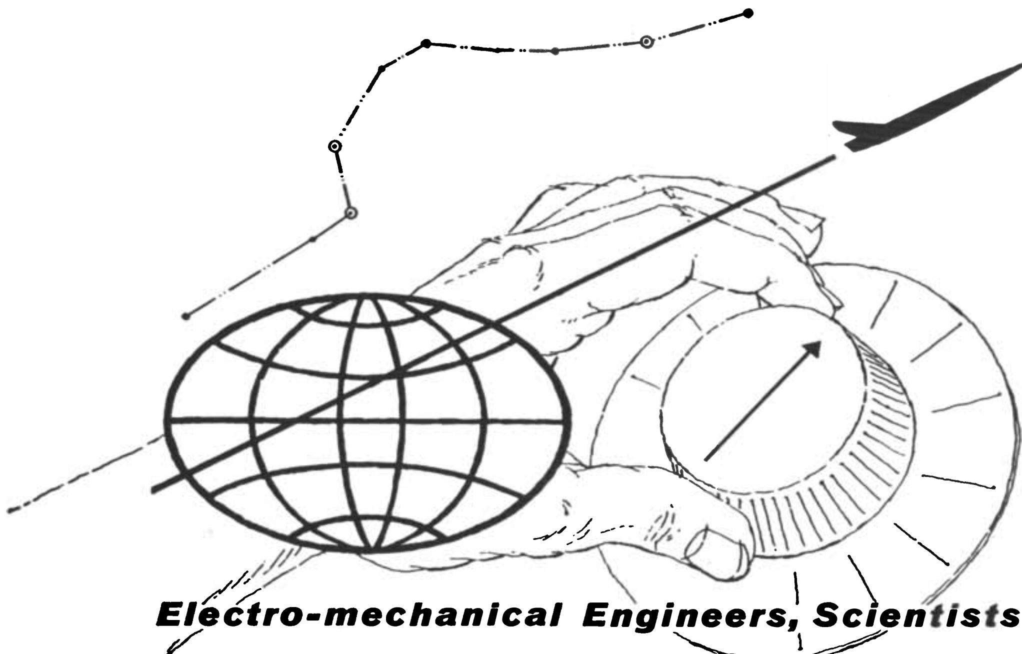
WHAT IS SCIENCE?, edited by James R. Newman. Simon and Schuster ($4.95). A dozen authors review and discuss theoretical research in the major scientific disciplines. The contributing authors are Bertrand Russell, Edmund Whittaker, Hermann Bondi, Edward U. Condon, John Read, Ernest Baldwin, W. C. Allee, Julian Huxley, Edwin G. Boring, Clyde Kluckhohn, Erich Fromm and Jacob Bronowski. There are biographical notes by the editor and a bibliography for further reading.

Notes

COMBUSTION PROCESSES, edited by B. Lewis, R. N. Pease, H. S. Taylor. Princeton University Press ($12.50). The second volume of a series called "High Speed Aerodynamics and Jet Propulsion."

ASTROPHYSICAL QUANTITIES, by C. W. Allen. John de Graff, Inc. ($10.00). A handbook of physical constants.

ANNUAL REVIEW OF NUCLEAR SCIENCE: VOL. V, edited by J. G. Beckerley and associates. Annual Reviews, Inc. ($7.00). The 1955 volume contains 14 articles covering topics such as electromagnetic transitions in nuclei, radiation chemistry, radiobiology, shielding, particle detection, radioautography, mass spectrometry.



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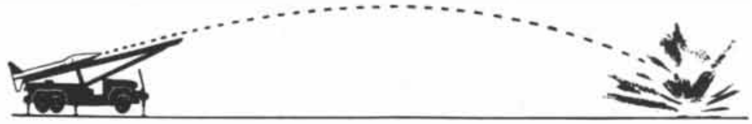

Defense is everybody's business. Development of Honest John by Douglas is an example of industry's role in U.S. defense. But weapons need people to make them work. The Army needs young men and women who agree that "defense is *everybody's* business."

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THE AMATEUR SCIENTIST

On the scientific study of tropical fish and a sundial for the ceiling of a room

A next door neighbor who normally makes a fetish of getting a full night's sleep rang our telephone at the outlandish hour of 2:00 a.m. the other morning. "My angel is laying eggs!" he exclaimed. "What should I do?" Our friend was referring, of course, to *Pterophyllum scalare*, otherwise known as the angelfish. We advised him to go to bed and let nature play midwife. As experienced keepers of tropical fish know, there was nothing else he could do. When conditions in the aquarium are proper for spawning—when the tank is clean, slightly warmer than usual and free of competing species—well-fed angelfish do not eat their eggs as a rule. If these requirements have not been met by the time the eggs arrive, you may as well relax and observe how nature disposes of potential weaklings.

Tropical-fish keeping does not involve much work—which is a major reason why it has become the third most popular hobby in the U. S. According to Leonard Berkitz of the Aquarium Stock Company in New York City, only photography and stamp collecting outrank tropical fish in popularity. About 20 million persons in this country have home aquariums. They spend some $70 million a year on their hobby and support a billion-dollar industry. Hundreds of commercial collectors search the tropical streams and pools of the earth for marketable specimens. One South American exporter maintains a large twin-engined airplane for the exclusive purpose of transporting miniature fish to New York City. The investment of individual fans ranges from as little as $5 (which the novice next door had laid out for his small tank and lone pair of angels) to as much as $35,000, which a New York businessman spent last year to decorate his Park Avenue duplex in a motif of recessed tanks filled with hundreds of rare specimens.

The average fan devotes about 10 minutes a day to his fish, but you may invest a great deal more time (and ingenuity), particularly if you enjoy the biological sciences. For $15 or $20 you can buy a dozen fish along with a handsome tank, plants, food, sand, an automatic filter, an aerator and a complete assortment of gadgets for handling the fish and keeping the tank clean. This fits you out with all you need for studying these fascinating bits of life in endless ways as they emerge from the egg and progress through courting, fighting, mating and old age.

With tens of millions of enthusiasts exploring the ways of tropical fish, one might suppose there is not much to find out that is not already known and published in reference books. Actually the books don't begin to answer all the questions that a curious amateur scientist will ask as soon as he becomes acquainted with his aquarium. The study of behavior alone can be a lifetime avocation, particularly if you go in for unusual fish. How, for example, does the weatherfish sense approaching storms? Just before a downpour it rushes around the aquarium in a frenzy. Experiments indicate that its agitation is triggered by changes in barometric pressure. If so, what part of the fish's body acts as the sensor and what advantage does the adaptation give the species? An aquarium fitted with an apparatus for varying the air pressure on the water might lead to interesting results. Then there is the archerfish, which shoots pellets of water with rifle-like accuracy at flying insects. It can score a bull's-eye on an insect a foot or more above the aquarium, although its eyes are below the water surface. How does the archer compensate for the refraction of light at the surface? That this is an important problem is shown by the fact that one species, an *Anableps*, is specially equipped with eyes divided into two parts, of which the upper part can adjust to seeing in air and the lower part to seeing in water. Other species of fish have periscopes, and at least one fish possesses a telescopic eye which should fascinate amateur astronomers.

Not many amateurs can afford these odd and comparatively scarce specimens. Most start off with guppies—the humble commoners of the tropical-fish world. In the past two decades geneticists have transformed the once-drab guppy into one of the most colorful creatures in the aquarium while using it as a subject for experiments in heredity. They have produced a number of attractive hybrid strains, particularly the platy-swordtails which appeared as by-products of Myron Gordon's researches into the genetic aspects of cancer at the New York Aquarium.

That amateurs can do successful research in heredity was shown by the experiments of Marita Mullan with mice,

Male and female guppies. One male is at the top; two females are at the bottom

Experimental aquariums for the study of pollution

which are far less convenient to work with than fish [see "The Amateur Scientist;" SCIENTIFIC AMERICAN, December, 1952]. Miss Mullan produced hairless mice, bushy mice and mice with coats of various colors. All bred true in succeeding generations. Her work differed from conventional breeding in that she used the laws of heredity, instead of merely following the classical rule of thumb that "like produces like." What Miss Mullan accomplished with mice other amateurs can do with fish, and with much less effort. Fish are not so messy nor do they eat as much.

What is the best diet for fish? This is another area of great interest among fish fans. The cliché among ichthyologists is that "the best food for fish is fish." Doubtless the rule holds for fish in the wild state. But most authorities now agree that it breaks down when fish are confined to an aquarium. Conditions in a tank are so different from those in tropical streams and pools that only a few hundred of the most hardy specimens survive shipment.

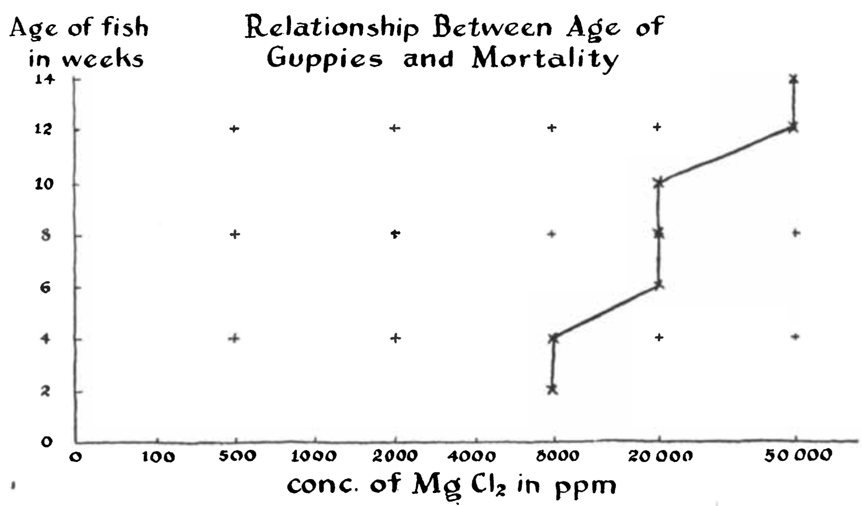
Leon F. Whitney, a veterinarian and authority on the guppy, recently made a start on the food question by measuring the proportion of water to dry matter in eight types of food usually given to tropicals. He found a great variation in the solid content of these foods—as much as 20-fold. The dry matter in *Tubifex* worms, *Daphnia*, bloodworms and brine shrimp ranges from about 4 per cent to 14 per cent; white worms average 23 per cent; commercial preparations (such as crushed dog biscuit) go as high as 93 per cent. These figures indicate why it is easy to kill fish by overfeeding when you give them dried preparations. Furthermore, there are many other things to consider besides the amount of solid content. Fish need certain percentages of fats, carbohydrates, proteins, vitamins and minerals. To keep them healthy, they should also have live food occasionally: dead worms, even if relatively fresh, fail to supply as much of some mysterious something as do worms that go into the tank alive. What element vanishes with the worm's death? Here is a challenging problem for an amateur with a background in biochemistry.

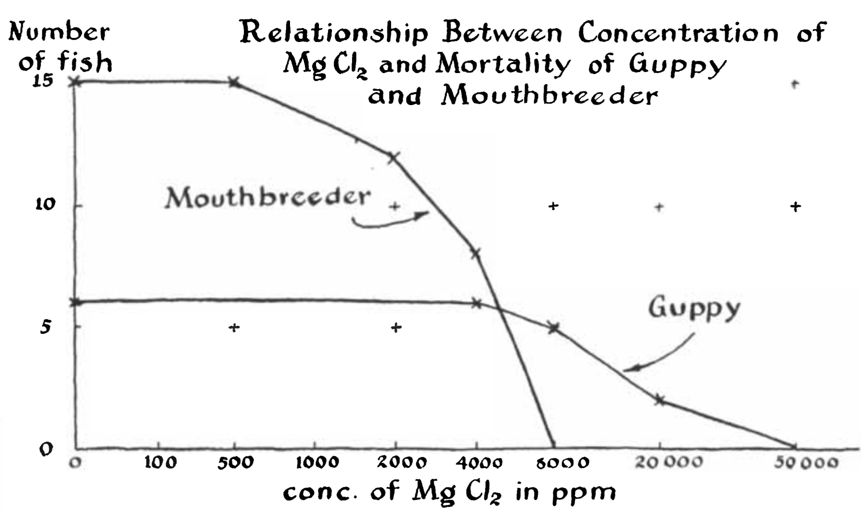
Equally subtle is the relationship between the fish and the water in which it swims. Christopher Coates, curator and aquarist of the New York Aquarium, has pointed out that fish tend to establish a chemical harmony between the fluids in their bodies and those in the

tank. By a kind of osmotic interchange the water in the tank becomes increasingly like that in the fish and *vice versa*. Thus each fish conditions its aquarium, so that in time you wind up with "guppy-water" or "swordtail-water," depending upon the species in the tank.

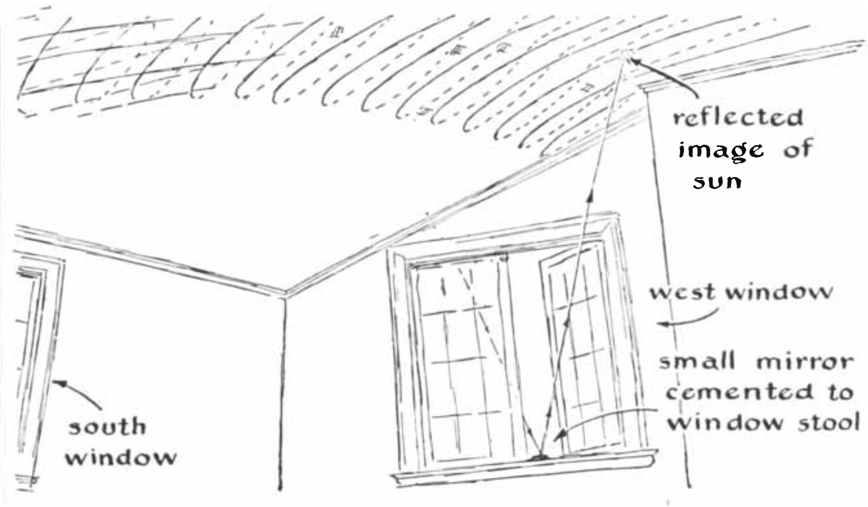
The fluids of most species of tropical fish kept in aquariums differ only slightly, so they can inhabit the same tank. But some are antagonistic to one another. You can observe this by watching a tank with a mixed population, at the same time keeping individuals of these species in separate tanks for comparison. The fish in the separate tanks will grow faster and do better generally. In the mixed community, after a time, some fish will lose their vigor, some will lose color, some will fail to reproduce. As the experiment progresses, it becomes clear that certain species are gaining the ascendancy, while others are dying out. Eventually you may be left with only one kind of fish in the tank.

The fish are also in competition with microorganisms that drop in from the air, arrive with the food, and so on. Some microbes infect them with disease. Others may be helpful, but recent experiments indicate that on the whole the fish would have the best chance of survival if they could live in an aseptic aquarium. Experimenters have raised fish of remarkable size and vigor by supplying antibiotics to the water continuously from the egg stage to maturity. How much of the result is due to the suppression of microorganisms and how much to the influence of the drugs on the organic processes of the fish has not been determined. The answer may come from an experiment now under way at several research institutions. Fish are be-





Charts showing the effect of polluted water on tropical fish



An amateur's indoor sundial

ing reared under sterile conditions. Eggs taken from the female by Caesarean section are sterilized in a solution of formalin and incubated in water hot enough to kill microorganisms. All the fish food is similarly sterilized. Preliminary reports indicate that giants are emerging from the experiment—fish twice the normal length and four times the weight!

Joel Rodney, a Brooklyn high-school boy who makes a hobby of chemistry, undertook a series of experiments in the opposite direction. He tested fish in water polluted by industrial wastes.

"Two years ago," he writes, "I came across an article in the New York *Times* which discussed the seriousness of pollution in Lake Michigan, particularly in the region of Chicago. I asked a friend who lives on the North Shore to bottle a sample of the lake water for me. Subsequent analysis showed a high concentration of magnesium chloride. I wondered whether the concentration was strong enough to kill fish native to Lake Michigan, but since I was a thousand miles from the scene, I had to settle for experiments that could be tackled in my bedroom.

"My subjects were guppies, which bear their young live, and the African mouthbreeder (*Tilapia macrocephala*), a species that lays eggs. Starting with six pairs of ordinary guppies, I bred several hundred within a few months, and from this stock I selected 108, ranging in age from two weeks to three and a half months. I divided them into 18 groups and placed each group of six fish in a glass jar containing three pints of water with a certain concentration of magnesium chloride. As a control, I also had two jars of guppies with uncontaminated water. All the fish were kept at a uniform temperature of 72 degrees by means of a 60-watt lamp bulb a few inches above each jar, which precisely compensated for the 10-degree nighttime drop in our thermostatically-controlled apartment. I raised some Tilapia in the same way; since they did not reproduce nearly so rapidly as the guppies, I had only five jars of them for the experiment, plus one as a control.

"I dried magnesium chloride over an open flame and then introduced a measured amount, weighed on an analytical balance, into each experimental jar, first dissolving the salt in a little water. I started with a concentration of 100 parts per million in the first jar, watched for the reaction of the fish, and successively increased the dose in the following jars, up to 50,000 parts per million. For the guppies the minimum lethal dose proved to be 8,000 p.p.m. The 50 per cent lethal dose (killing half the fish) was 20,000 p.p.m. For Tilapia the minimum lethal dose was 1,000 p.p.m. and the 50 per cent lethal 4,000 p.p.m. Tolerance for the poison increased with age: the oldest fish could withstand six times as high a concentration as the youngest [*see charts on page 144*].

"After the experiment had been running a few weeks, I learned to predict probable mortality by observing the behavior of the fish when the poison entered the water. Hardy specimens tended to swim around the tank, at a slightly faster than normal rate. Those more affected swam in a figure 8. The most injured darted up and down between the surface and the bottom of the tank. You often note erratic behavior like this on transferring fish from one tank to an-

E. D. McArthur, M.S., Union College, joined the General Electric Company in 1925 and for many years was in charge of advanced development for the vacuum-tube engineering department. During World War II he was on special assignment with the U. S. Navy, receiving a Certificate of Commendation. Since 1950 he has been at the G-E Research Laboratory as manager of the Electron Tube Section. In 1954 he won a National Electronic Conference award, adding to the honors he has received in connection with development of "Lighthouse tubes."

Advances in tube design

E. D. McArthur leads General Electric development of disk-seal tubes using cavity-resonator principle

"Lighthouse tubes," the famous World War II radar tubes which got their name from their appearance, truly have lighted the way to a revolution in electronic devices. E. D. McArthur created them by combining his *cavity-resonator* concept, which made tubes virtually self-shielding, with the unique *disk-seal* design, in which simple disks and cylinders served as conducting elements and tube envelope. "The disk tube," in McArthur's words, "was an embodiment of the principle that in the microwave field we could no longer speak of tubes and circuits as two distinct entities . . . but rather as a single electrical system." Over the years, disk tubes have become essential to coast-to-coast TV transmission and have lengthened the arm of radar defense. Using new materials and methods, the men in McArthur's Electron Tube Section at the G-E Research Laboratory have developed microminiature ceramic tubes, now finding their first use in TV receivers. These tubes reflect the functional simplicity and superior electrical performance he envisioned nearly 20 years ago when he made a "dummy" model to show how the cavity-resonator principle could be applied to triodes.

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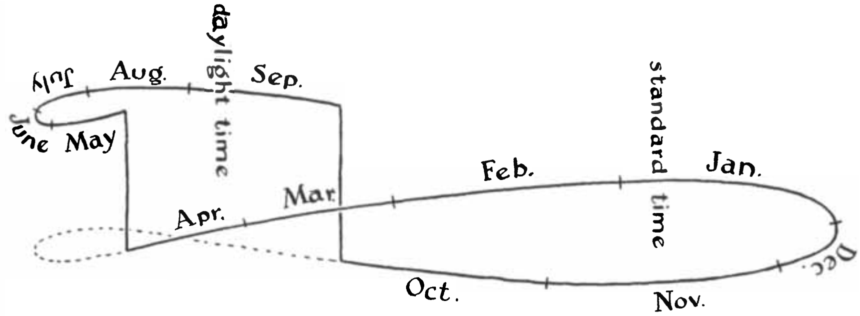


An analemma, with offset for daylight-saving time

other. When I commenced working with fish, I supposed they behaved that way because of fright aroused by the handling. Now I wonder whether chemical differences in the water may not account for it, at least in part."

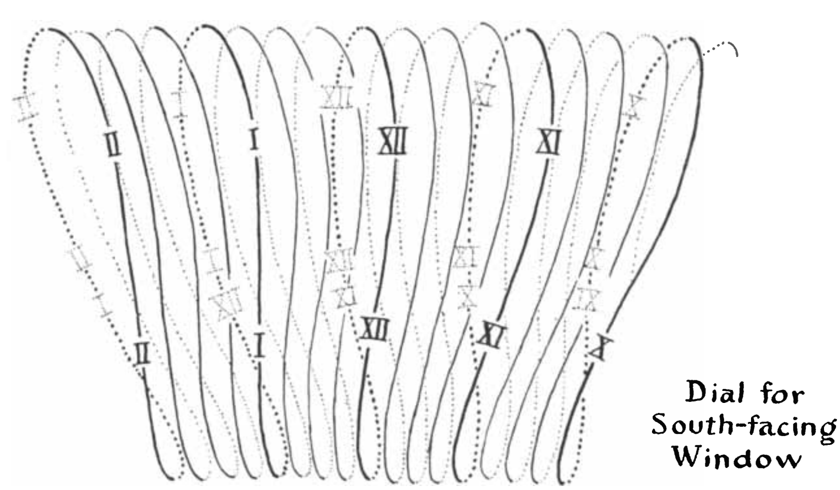
Rodney's paper describing this work won a Westinghouse Science Talent Search award, landed a summer job for him with the American Museum of Natural History and helped win a scholarship under which he is now studying at Brandeis University.

A design for an unusual indoor sundial has been submitted to this department by Rear Admiral Garret L. Schuyler, U.S.N. (Ret.) of Washington, D. C. His dial also serves as a calendar, occasionally as a wind vane and as a novel decorative scheme for your den, should your taste run to abstract art [*see drawing on page 146*].

"First select a window sill which gets direct sunshine for a couple of hours each day," says Admiral Schuyler. "Inside the window, and well back on the horizontal sill-surface so as to avoid the shadow of the bottom of the window frame when the sun is low in winter, stick a 5/8-inch-square mirror face upward, using Duco cement. The sun's rays will be reflected upward from this small mirror and, even if they should have to pass through a light rayon curtain, they will make a small, roundish spot of light which travels across the ceiling as the sun's position shifts.

"At some selected time of day, say noon, mark the position of the image on the ceiling with a tack or an inconspicuous cross. Record the date with this mark. Repeat the process at weekly intervals as the seasons change and the sun travels north or south. Now if you draw a smooth curve on the ceiling through all the marked points, you will be able to tell noon of each day as the moment when the sun's image touches a point on this line. If you also mark its position on the curve on the first day of each month, you can closely estimate the day of the month from the image's crossing on any day.

"Such a curve, labeled 'analemma' and marked with the months of the



Hour and date lines for an indoor sundial

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ROCKETDYNE is North American's rocket engine division. It has just moved into new ultra-modern headquarters in Canoga Park, located in the beautiful West San Fernando Valley of Los Angeles. This area is famous for its fine residential sections, modern shopping-center convenience, varied recreational and entertainment facilities. Any point in the San Fernando Valley is just minutes drive from the beaches, and the weather is pleasant all year around. Many engineers are interested in advanced courses offered by fine schools like UCLA, USC, and Cal Tech, all within a short drive from our headquarters.

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B U I L D E R S   O F   P O W E R   F O R   O U T E R   S P A C E year, is often reproduced on geographical globes in the conveniently open area of the Pacific Ocean. Our curve on the ceiling is this same analemma—reversed by reflection, distorted by oblique projection on the ceiling, and modified by two sudden displacements where the time changes from 'Standard Time' to 'Daylight Time' and *vice versa.* But even though the mirror is canted and the ceiling may be somewhat irregular, the method described will establish a time-of-day curve without resort to mathematics or the usual correction devices required by sundials.

"A single line is perhaps all that many persons will want, but by constructing a series of lines corresponding to the hours and quarter-hour intervals one can readily make a complete sundial. Care must be taken, however, to distinguish the parts of the lines which are traced when the sun is traveling south (June to December) from those when it is traveling north (December to June). One set of markings may be traced by solid lines and the other by dotted lines. In practice it is convenient to use Scotch tape for marking the lines, one set in red tape and the other in black. The resulting design is both attractive and easy to read. The design's interest can be heightened and its utility doubled by making two sundials: one from a south window and one from a west window of the same room with the lines crossing.

"The traveling spot corresponds to the sun's image in a pinhole camera, the 'pinhole orifice' being replaced by the small mirror. At close range the spot is somewhat rounded but the same size as the mirror. Farther away the width is approximately equal to the diameter of the mirror multiplied by .009 times its distance from the mirror. At 10 feet the 15-minute lines will be spaced about 10 inches apart. Time can easily be estimated to the nearest minute.

"If you watch carefully, cloud formations can often be seen drifting across the sun's disk. Thus the indoor sundial acts as a vane showing the direction of the wind. This effect could doubtless be heightened by inserting a spectacle lens of appropriate focal length in the beam—but I have not added this refinement.

"For a shut-in person, or for anyone persistent enough to pursue the project for a whole year, we can think of no easier or cheaper hobby than constructing time-of-day lines for sundials of this sort. And between the convenience and comfort of reading an outdoor sundial in wintry weather and reading one on the ceiling, we submit that there can be hardly any comparison."

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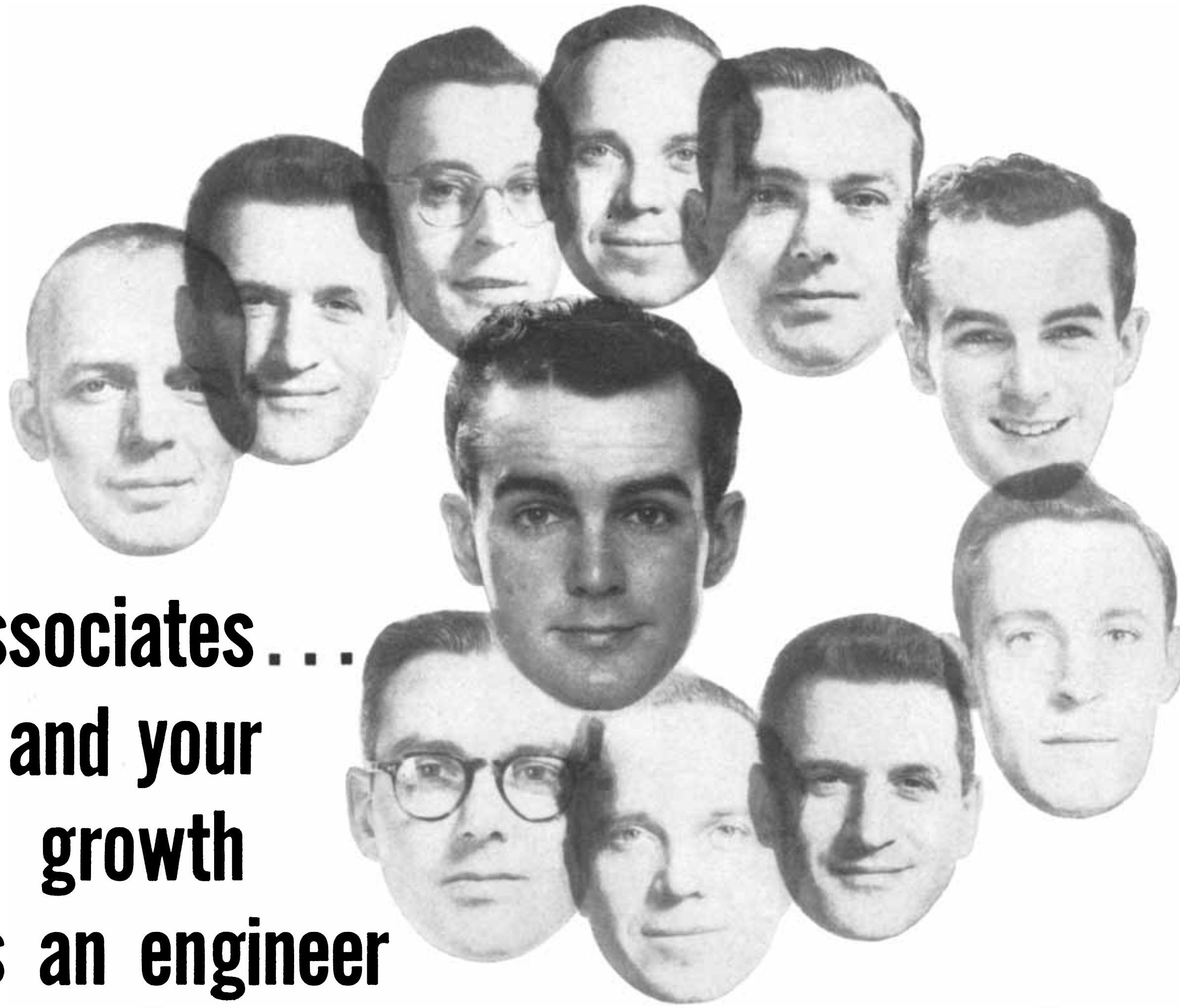

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