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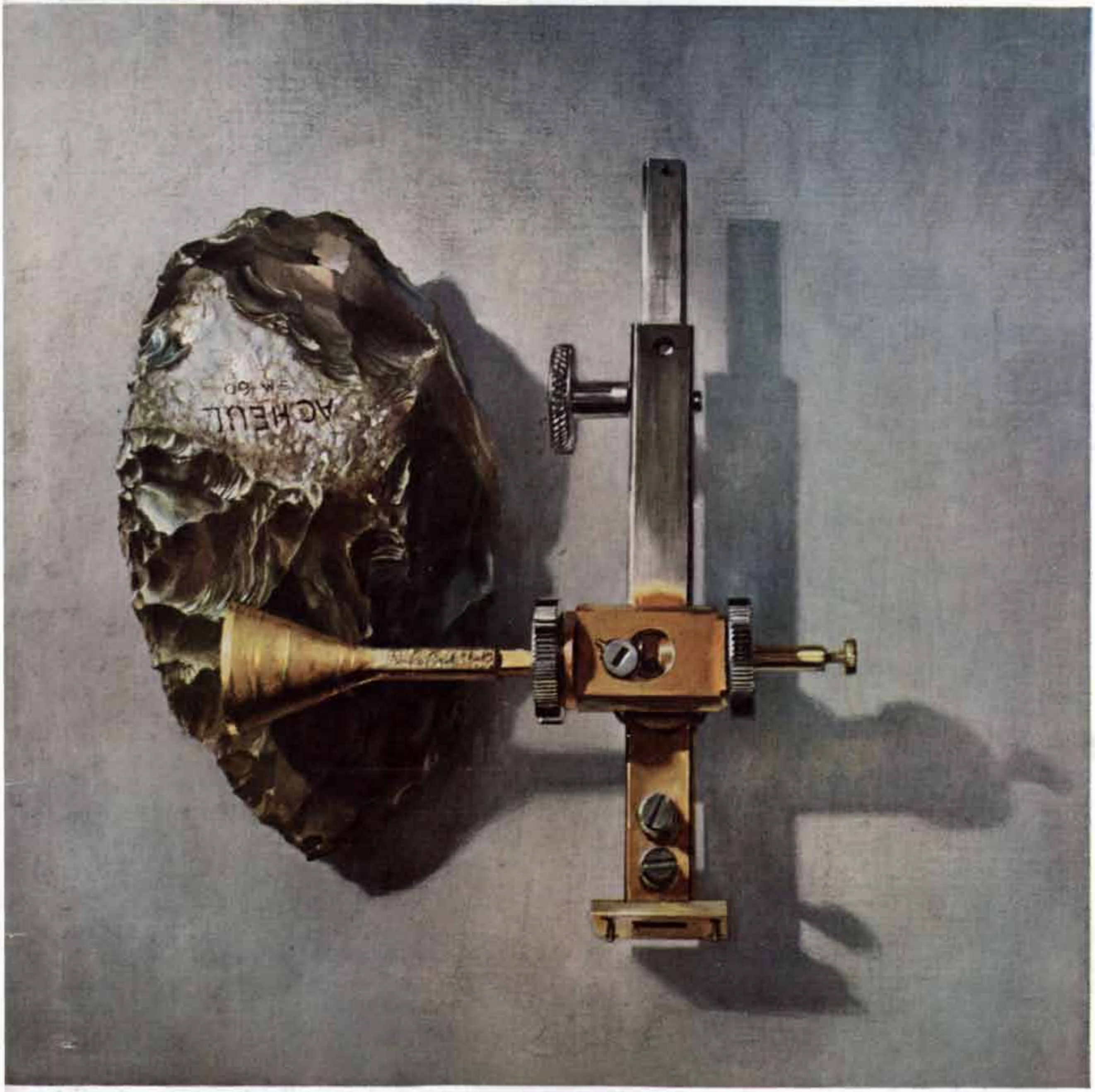

THE HUMAN SPECIES

FIFTY CENTS

September 1960


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"An entirely new character has been given to the whole of our modern civilization, not only by our astounding theoretical progress in sound knowledge of Nature, but also by the remarkably fertile practical application of that knowledge in technical science, industry, commerce, and so forth. On the other hand, however, we have made little or no progress in moral and social life, in comparison with earlier centuries; at times there has been serious reaction. And from this obvious conflict there have arisen, not only an uneasy sense of dismemberment and falseness, but even the danger of grave catastrophes in the political and social world. It is, then, not merely the right, but the sacred duty, of every honorable and humanitarian thinker to devote himself conscientiously to the settlement of that conflict, and to warding off the dangers that it brings in its train."

—Riddle of the Universe, 1900

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Established 1845 SCIENTIFIC AMERICAN September, 1960 Volume 203 Number 3

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THE COVER

The still life on the cover symbolizes a central theme in this issue of SCIENTIFIC AMERICAN, which is devoted to the rise of the human species. At left is an Acheulean hand ax, chipped out of flint at least 150,000 years ago. At right is a tool of 20th-century man: a microwave frequency converter. Stone tools have been found that are about a million years old. At one time they were taken as evidence that man had evolved a million years ago. Now, however, it appears that *Homo sapiens* originated only between 150,000 and 50,000 years ago. Thus the first tools must have been taken up by prehuman primates. Indeed, the use of tools by these primates was undoubtedly one of the principal forces that caused them to evolve into men.

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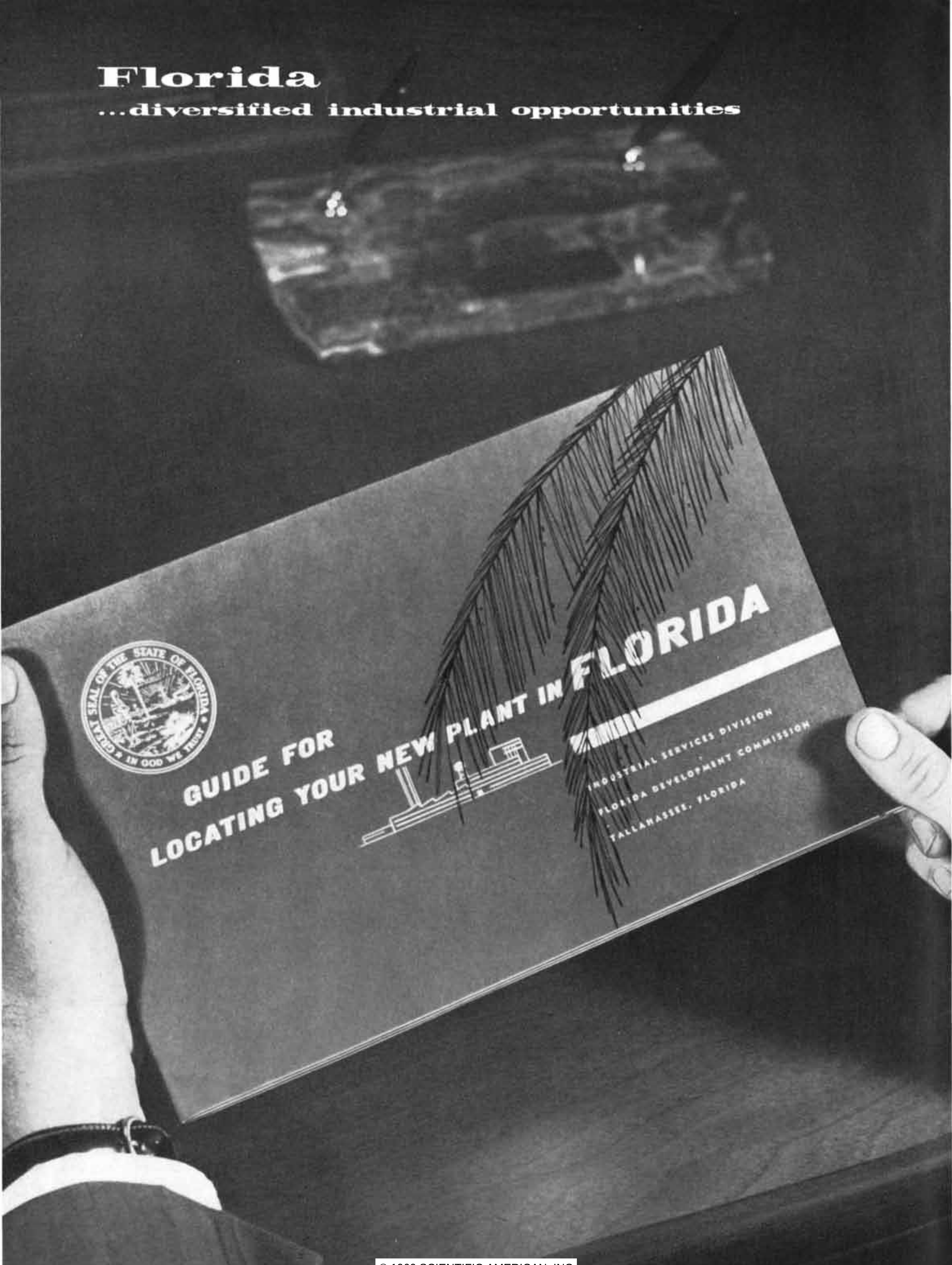
Florida
...diversified industrial opportunities
GUIDE FOR
LOCATING YOUR NEW PLANT IN FLORIDA
INDUSTRIAL SERVICES DIVISION
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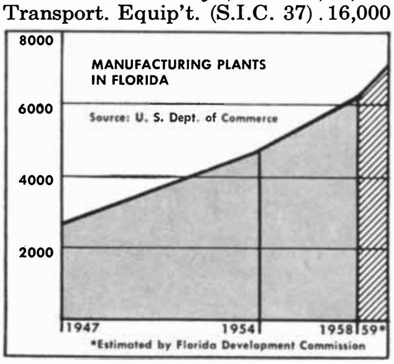
In rate of industrial growth, Florida ranks an easy first among the major states. But even more significant from the standpoint of those considering new ventures is the increasing diversification of the state's economy.

Here is a solid foundation for future expansion. Here is evidence of the opportunity which exists in many lines.

A total of almost 7,000 plants — a third of them less than five years old — make manufacturing the most dynamic of the state's industries. Two hundred thousand people are now employed, and no single category dominates the picture. Typical employment figures for 1959 include:

Apparel (S.I.C. 23)	8,100
Furniture & Fixtures (S.I.C. 25)	8,500
Pulp & Paper (S.I.C. 26)	13,100
Chemicals (S.I.C. 28)	15,800
Stone, Clay, Glass (S.I.C. 32)	13,800
Fabricated Metals (S.I.C. 34)	14,100
Machinery Ex. Elec. (S.I.C. 35)	5,500
Electrical Machinery (S.I.C. 36)	8,900
Transport. Equip't. (S.I.C. 37)	16,000



The steady increase in manufacturing plants is evidence of the number of new ventures which find opportunity for growth in Florida.

EMPLOYMENT MORE THAN DOUBLES

In all of these manufacturing categories, except pulp and paper which showed a 75 per cent gain, employment has more than doubled in the last decade. And in every case, the Florida increase has been at least three times the national increase in these industries.

Research activities, growing rapidly in Florida, account for a substantial part of this increased employment.

Electronics is not classifiable as a separate industry, but workers in electronics make up a major portion of the estimated 30,000 persons engaged in precision manufacturing in the state.

← New booklet explains in detail how the Industrial Services Division of the Florida Development Commission is equipped to help you select the most advantageous location in the state for your new plant or branch. Write for it today. All inquiries confidential.

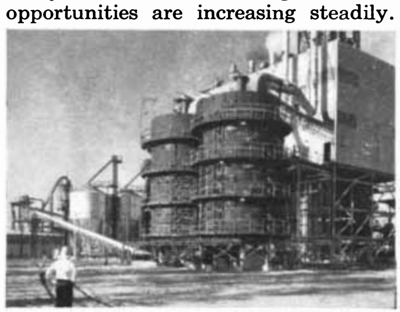
As Florida begins to realize its industrial potential, opportunities increase. In 1959 alone, 783 new plants and major expansions were announced. All parts of the state shared in the growth, and rural areas accounted for more than 20 per cent of the total.

But manufacturing is only one of many contributors to Florida's economy.

A WELL-ROUNDED ECONOMIC BASE

Non-farm building construction, resulting largely from the state's industrial expansion, totaled more than $1.4 billion in 1959. Over 130,000 are employed in building plants, offices and highways, and homes and schools for Florida's new workers.

Suppliers to the building trades find ready markets for their goods, and opportunities are increasing steadily.



The Michigan Chemical Corporation, which opened this plant to recover magnesium oxide from the sea at Port St. Joe in 1959, is an important factor in the growing chemical complex centered in northwest Florida. Employment in the chemical industry in the state has more than tripled in the last decade.

Foreign trade through the state's 13 deep water ports exceeded half a billion dollars in 1958 and is growing.

Florida's mines yielded $159 million in 1959—more than double the production of ten years earlier.

FARMS — FORESTS — TOURISTS

Florida's forests are a self-perpetuating source of lumber products as well as raw materials for the state's pulp, paper and chemical industries. Wholesale value of products derived from these forests exceeded $450 million in 1958.

Cash farm income in Florida reached a high of $788 million in 1959—up 61 per cent from 1950. The national gain for the period was 16 per cent.

Eleven million tourists spent one and two-thirds billion dollars in the Sunshine State in 1959. Almost a billion of this was spent on retail purchases alone to swell the state's already large consumer market.

FLORIDA-GROWING ON EVERY FRONT

In population, Florida is now tenth among the states. In 1950, it ranked 20th. The state's 4.8 million permanent residents represent a 72 per cent gain during the last decade . . . a rate of growth three times the nation's average.

Retail sales totaled $5,840 million in 1958. Per capita sales of $1,293 compared with a national average of $1,156.

Electric power output has more than tripled in the last 10 years and capacity now exceeds 3.8 million kilowatts.

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If you are seriously considering locating a plant or branch in Florida, special studies can be prepared, tailored to your needs. These can cover markets, manpower, transportation, supplier industries or other factors of importance to you. Reports may be on either a state-wide or regional basis.

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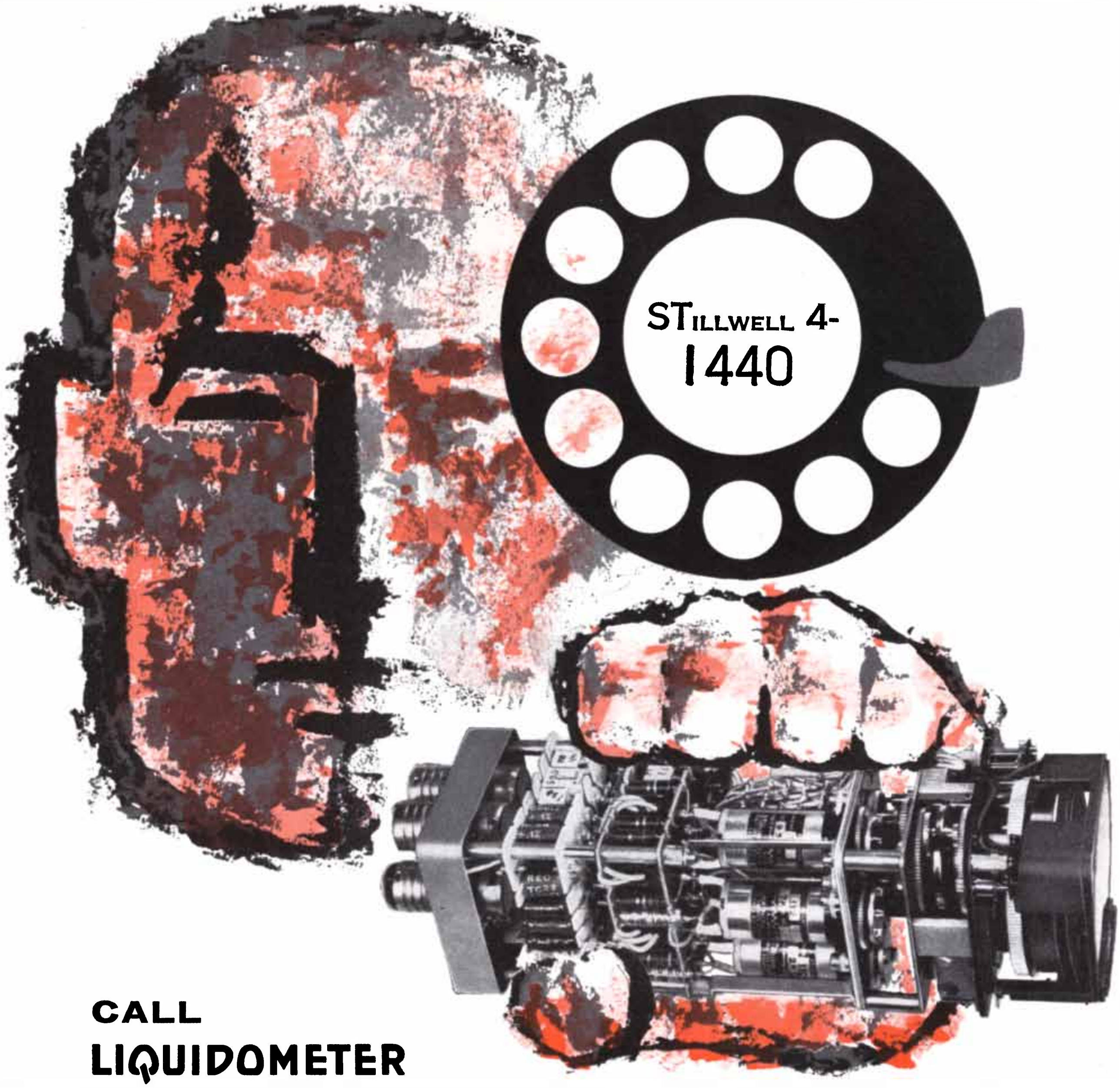
For more general information about industrial Florida, ask for the file folder, Profile of Progress, *covering resources, research, power and water, climate and living conditions, taxes and government and industrial growth as well as markets, manpower and transportation.*

See industrial Florida for yourself. Write State of Florida, Dept. B, Carlton Building, Tallahassee, for a 100-page "Vacation Guide."



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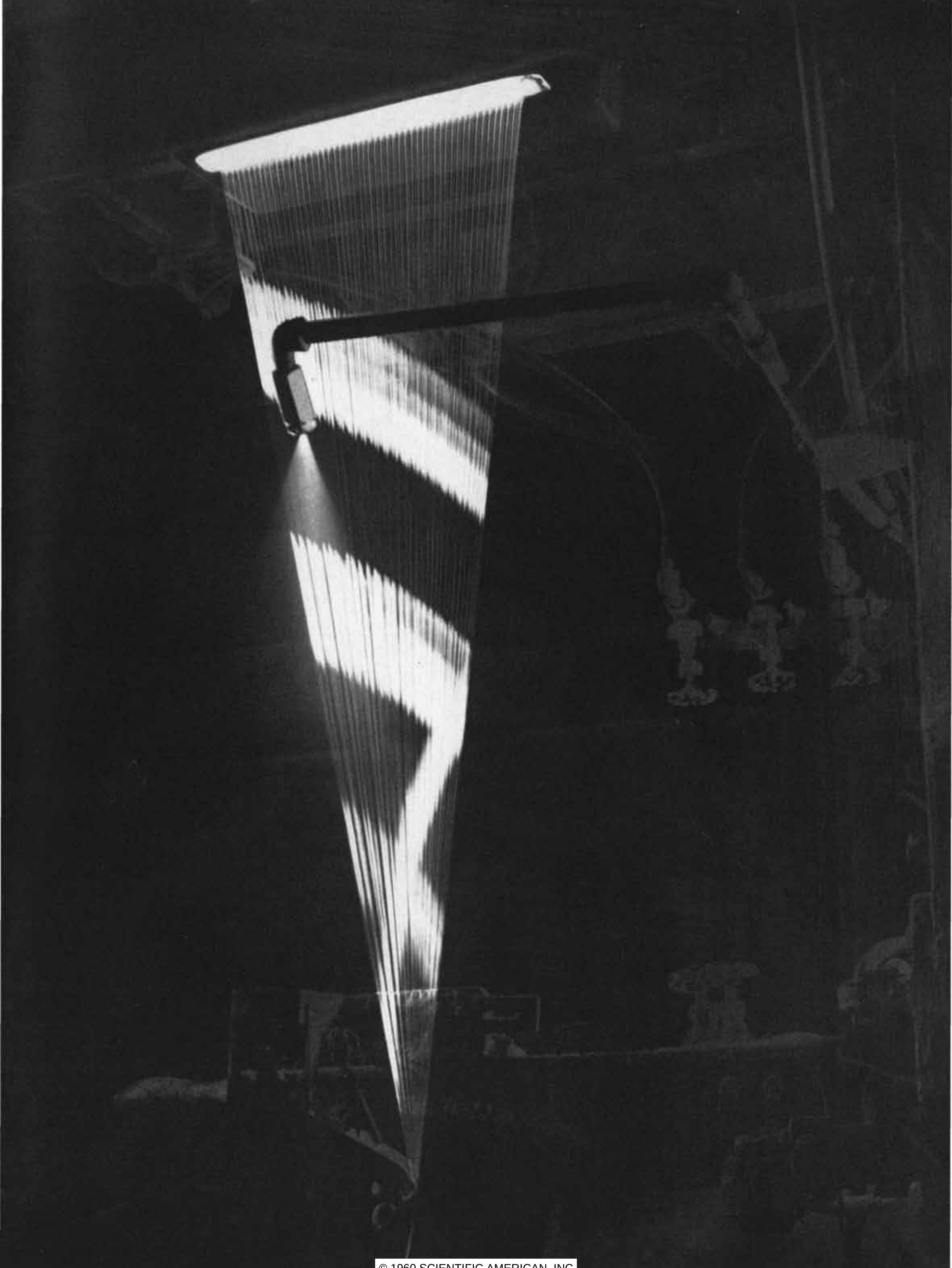

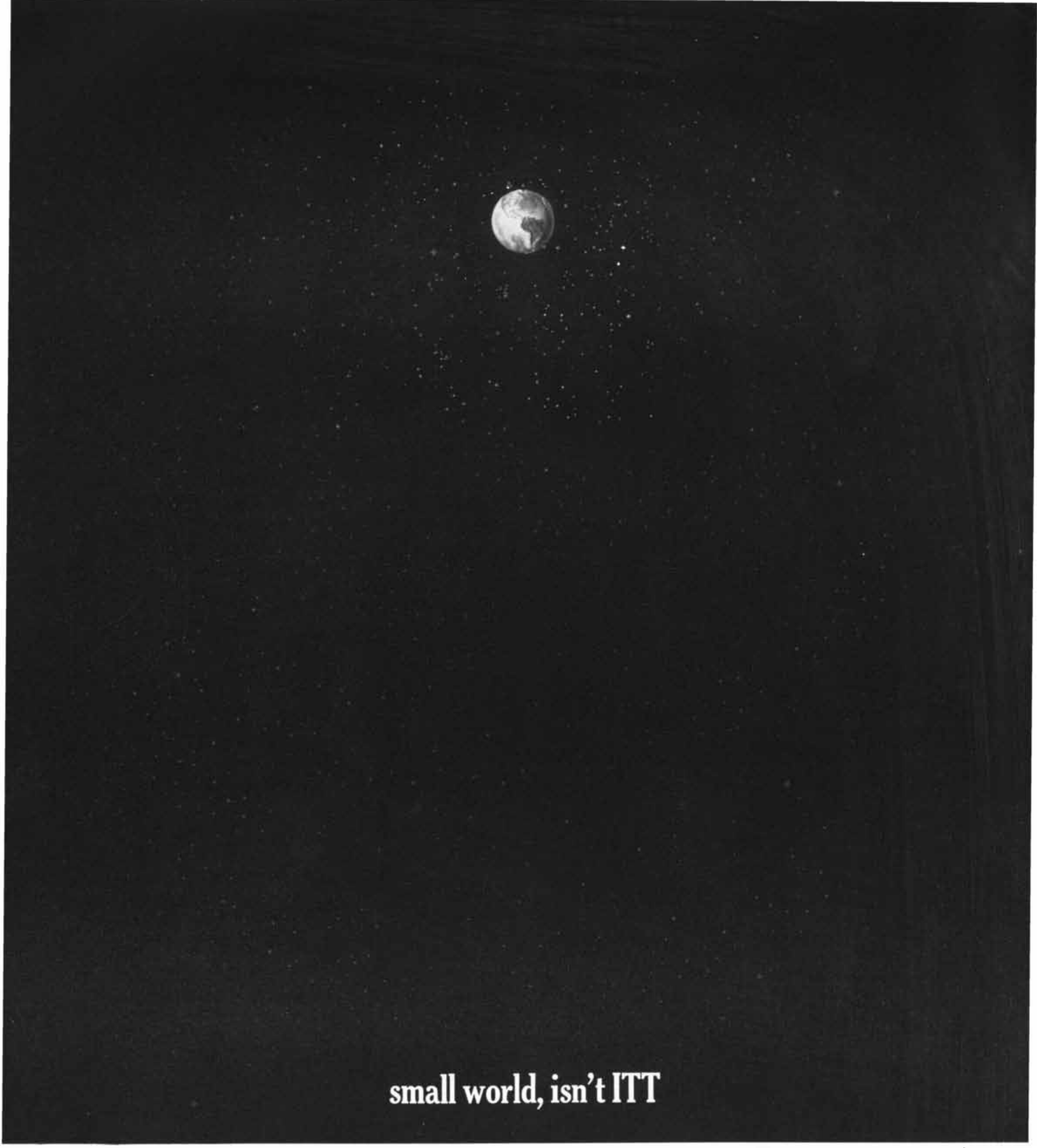

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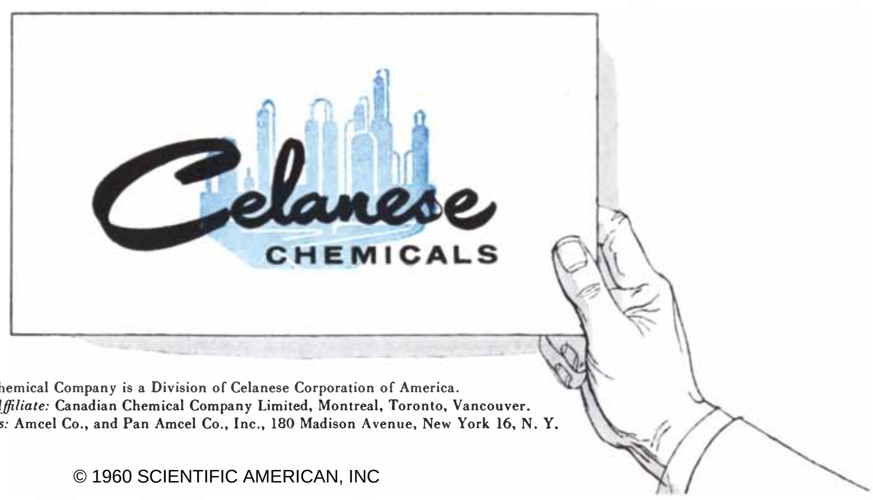

LETTERS

Sirs:

Sergio DeBenedetti's right to call himself "an obstinate humanist and classicist" had been questioned by some of your correspondents ["Letters"; SCIENTIFIC AMERICAN, July] because he, allegedly in error, stated that the Greeks revealed a deep understanding of the importance of time when they made their chief divinity, Zeus, into a son of Kronos, the god of time. It is true that for a person who consults a dictionary the name Kronos is different from the Greek term *chronos*, meaning "time"; but the facts appear different to a person acquainted with classical literature. The association of Kronos, father of Zeus, with *chronos* is well established in poets of the fifth century B.C. This association is as old as the first Greek speculations on the nature of time in the preceding early period of Greek culture. The references may be found under the entry "Kronos" in the standard reference works for classical studies, such as *Real-Encyclopädie der Klassischen Altertumswissenschaft* and Roscher's *Ausführliches Lexikon des Griechischen und Römischen Mythologie*. It is because of Kronos's association with time that his name was given to the most distant of the seven heavenly bodies; in pre-Greek Oriental chronological systems a particular significance is given to this planet, Saturn for us, because it concludes its orbit in 30 years, so that a day in its year corresponds to a month in the earth's year.

The specific philosophical interpretation of the myth of Kronos that DeBenedetti had in mind is assumed in the discussion of the concept of time in Plato's *Timaeus*, and in the pseudo-Aristotelian treatise *On the World*; it is extensively exploited by Stoic philosophers.

When the Romans identified their own god of agriculture Saturnus with the Greek Kronos, they made the former into a god of time. As a result, today we portray Father Time with a sickle. The transformation of a rural figure into a philosophical concept was complete by the time of Cicero, who states (*On the Nature of the Gods*, II, 25): "Saturnus was chosen as the one to have as his province the intervals and cycles of time. In Greek this god is called by the very word *time*, since Kronos is the same as *chronos*, that is, time. We call him Saturnus because he saturates himself with years."

The etymological connection of the two words *Kronos* and *chronos* has been positively affirmed by some linguists and strongly denied by others, because, on the one hand, the semantic similarity of the two words is evident and, on the other, from a technical linguistic point of view, the difference between the *K* and the *ch* is most significant. The debate is still unsettled; if the two words are etymologically related, the common element is indicated by the Greek word *geron*, "old man."

DeBenedetti's memories from his classical education in Italy were correct. Let us hope that in spite of the criticism which, as he says, put him "in a position of embarrassment and confusion," he will continue in his effort to connect his active knowledge of modern science with his sound feeling for the insights contained in Greek myths.

LIVIO C. STECCHINI

Princeton, N.J.

Sirs:

In his article on Humphry Davy [SCIENTIFIC AMERICAN, June] L. Pearce Williams mentions only briefly Davy's activities as president of the Royal Society (". . . he attempted to raise the scientific level of its members, a reform that was to be accomplished only after his death."). It seems only fair to set beside the story of his encouragement of Faraday another episode, not so well known and less creditable to Davy.

In 1820 John Herapath submitted to the Royal Society an account of his theory of gases and liquids, based on the hypothesis that the heat of a substance consists simply in the motion of its constituent molecules and atoms. Herapath deduced the gas laws of Boyle and Charles (or Mariotte and Gay-Lussac) by considering the impacts of molecules on the walls of their container—in this he was anticipated by Bernoulli in 1738—and then gave a good qualitative description of many other phenomena from a kinetic viewpoint. While his theory contained some errors, it was essentially correct, and had the Royal Society given Herapath due recognition, he might now be better known as a founder of the kinetic theory. In fact, few physicists today ever heard of him.

Of course the primary reason for the rejection of Herapath's theory was that it was in conflict with the caloric theory of heat, then generally accepted; it seemed to be pure speculation, lacking any sound experimental evidence. But Davy, who opposed the publication of the paper, had himself rejected the caloric theory as a result of his own experiments, as Williams points out, and had expressed the opinion that heat is molecular motion. In a letter to Herapath, Davy said: ". . . although I must confess myself not satisfied with the ultimate deductions, yet I was much pleased with the great ingenuity displayed throughout the whole; but I entertained my doubts on the propriety of laying before the Royal Society anything so abstruse and metaphysical."

Herapath then published his theory in *Annals of Philosophy* but, having been discredited by the Royal Society's rejection, it attracted little favorable attention and was soon forgotten. Fifty years later the same theory, now attributed to Kronig, Clausius and Maxwell, was accepted by a majority of physicists. (For further details and references see *Annals of Science*, Volume 13, Number 188; 1957.)

STEPHEN G. BRUSH

Lawrence Radiation Laboratory
University of California
Livermore, Calif.

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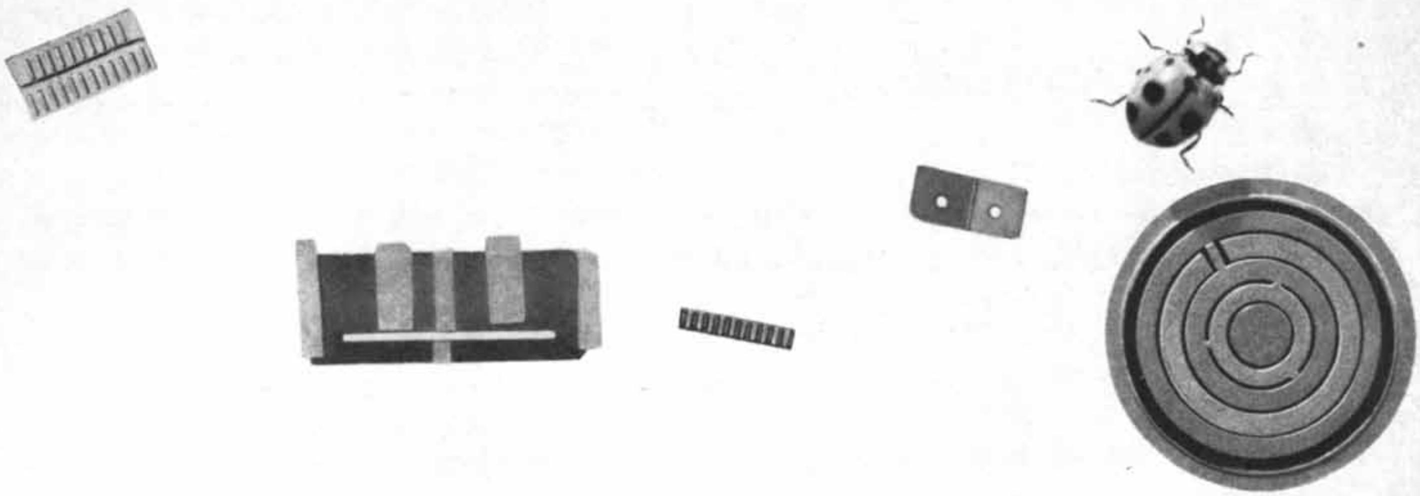

ENLARGED THREE TIMES—shown left to right are examples of Westinghouse functional electronic blocks: multiple three-terminal p-n-p-n switch; bistable multivibrator; multiple two-terminal p-n-p-n switch on dendrite; pulse generator; two-stage power amplifier.

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Functional electronic blocks perform complete circuit or sub-system functions within single semiconductor wafers or blocks. The functions are accomplished without the use of individual active or passive components, or inter-connections. The only connections to the blocks are those required for input and output terminals in power supplies. Thus, the functions are performed with great reduction in sub-system size and weight, and, as a result of the radical decrease in number of parts and inter-connections, it is reasonable to expect that system reliability will be improved.

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Samples now available

In order to expedite the adaption of the functional block concept to systems design, Westinghouse is making available, on a developmental sample basis, the following functional electronic blocks: Two-stage power amplifier/Three-stage power amplifier/Bistable multivibrator/ Pulse generator/ Ten-position multiple three-terminal switch.

The available types of functional electronic blocks will be extended in the coming months to include a variety of low-level amplifiers, additional multivibrators and switches. Your inquiries on the blocks now available as samples and on the development of other functional electronic blocks for your specific needs are invited. Call, or write: Westinghouse Electric Corporation, Semiconductor Department, Youngwood, Penna. SC-1003

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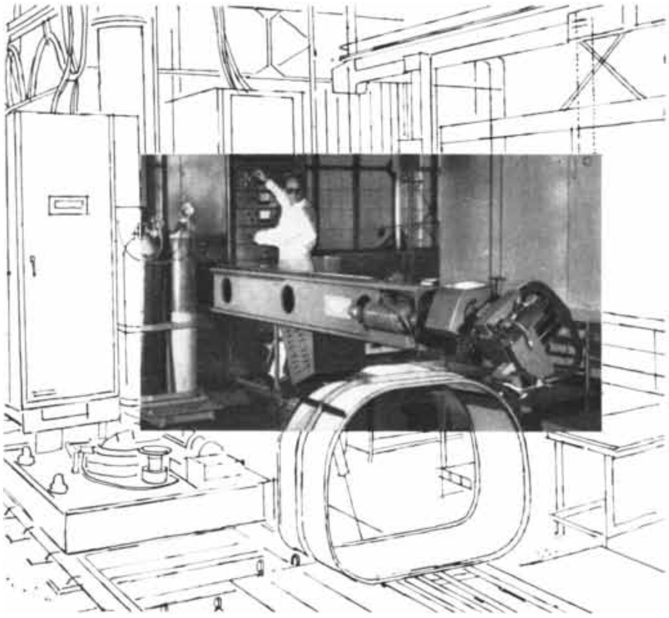

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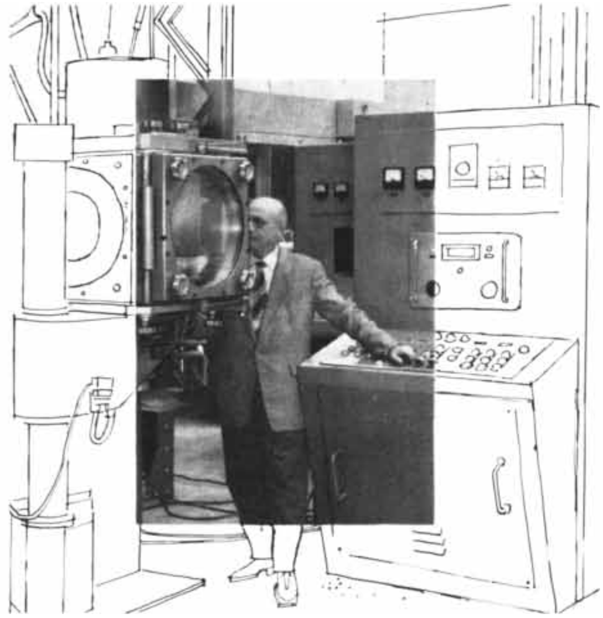

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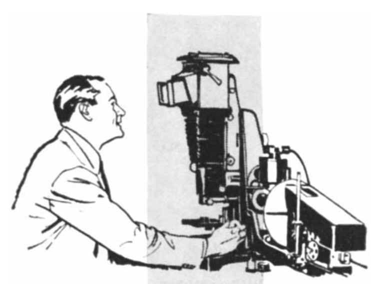

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Shedding light on the mysteries of life

So sensitive that it can detect the first irregular rhythm of a failing heart, so fast that it responds instantaneously to the waves of a troubled brain, the electron tube is helping to conquer the ills of the human body—as it is helping man to conquer space.

Heart of the electronic system, this "Lamp of Light" is working miracles in the field of medical research, diagnosis and therapy...sounding the depth of the anesthesia, gauging the vital fluids of the human body...measuring growth of the living cell...reacting to minute physiological changes.

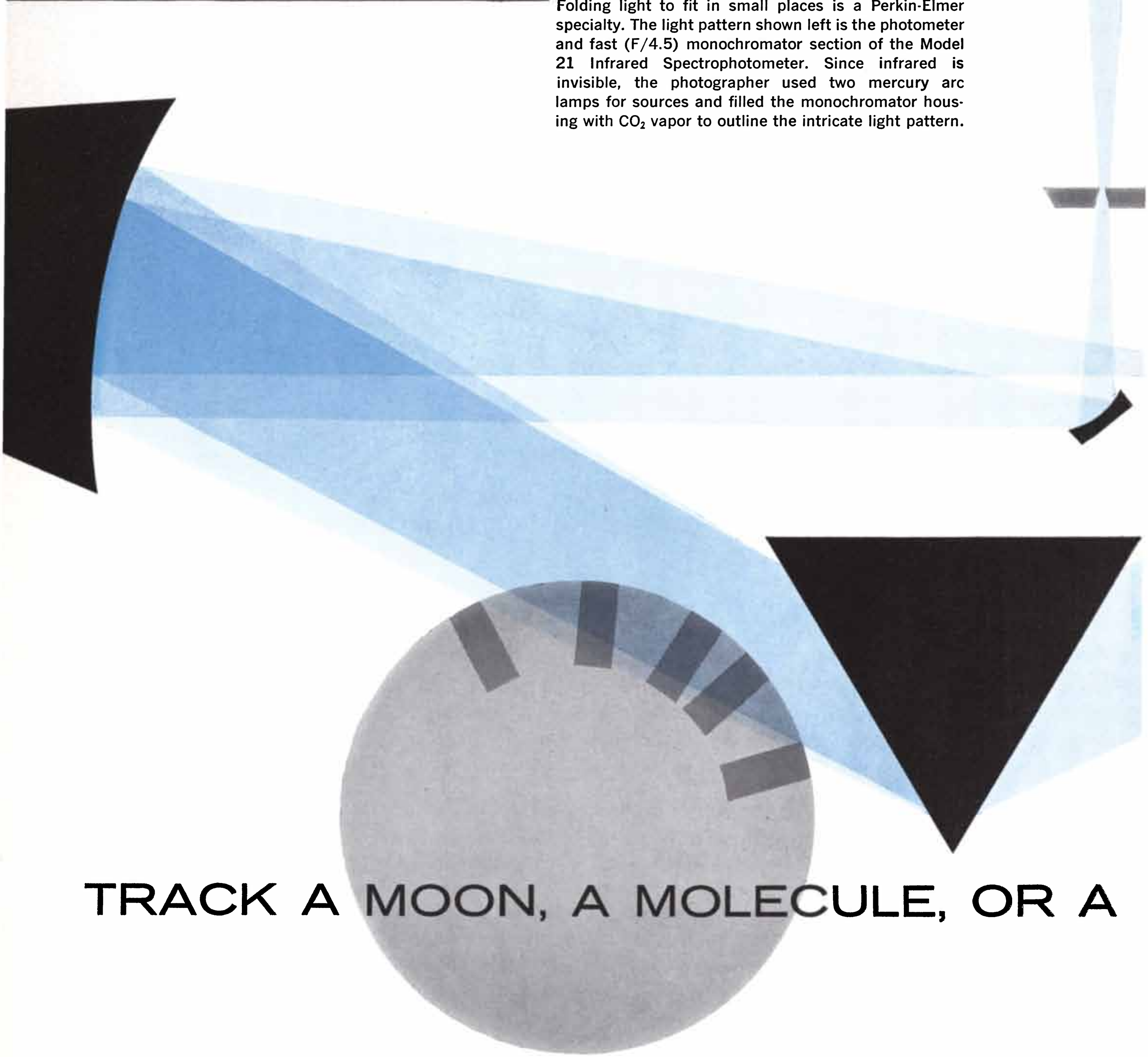
Little wonder that the electron tube captures the imagination of the scientific investigator. Its efficiency is unsurpassed—throughout the entire usable radio spectrum. Electrical characteristics are virtually unaffected after long use...long standby periods...temperature extremes. Performance is predictable with certainty.

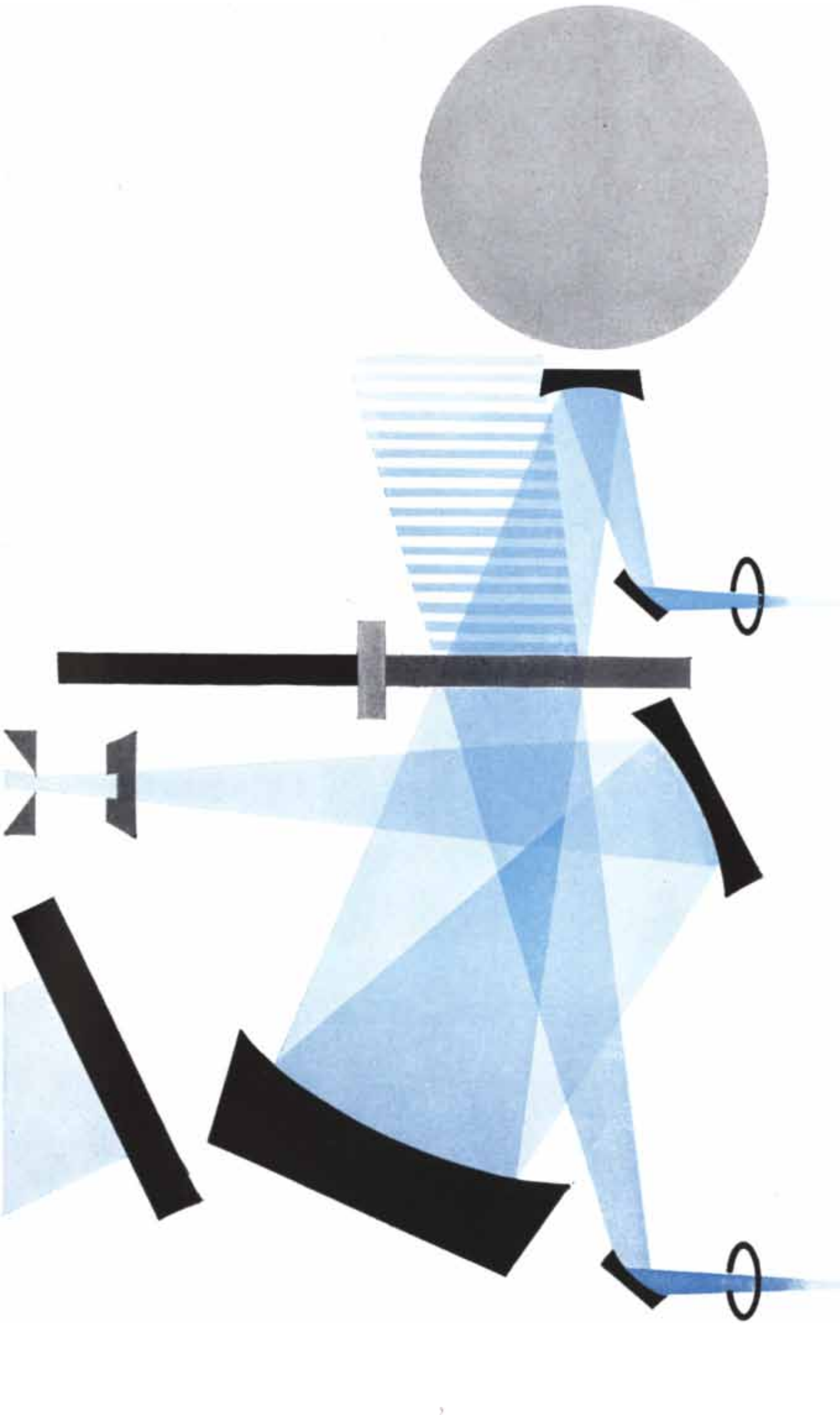
And yet tube research continues—everlastingly. Witness, for example, the nuvistor breakthrough. So small it fits inside a thimble, the revolutionary nuvistor just begins its work where the conventional tube leaves off.

If electronics is of great moment in your program for the future, you should evaluate the unique advantages of versatile RCA Electron Tubes. They have been serving mankind for nearly half a century.

RCA Electron Tube Division, Harrison, New Jersey

The Most Trusted Name in Electronics
RADIO CORPORATION OF AMERICA





Measure the flaming streak of a missile hurtled from Cape Canaveral — project a continent in an astronaut's lap — define a cortisone molecule or a coffee's aroma. These are the jobs Perkin-Elmer's capabilities are designed to do.

Advanced techniques such as gas chromotography, infrared and ultraviolet spectroscopy are fingerprinting chemicals, separating fifty component mixes, spotting air contaminants, monitoring process streams. At these frontiers, P-E **Analytical Instruments** provide fuller information faster and more precisely than ever before.

In space and defense technology, P-E **Electronic-Optical Systems** are pointing the inertial guidance platforms of the missiles, photographing their attitude and plume . . . recording the satellites, charting the heavens and the ground below . . . providing the earth-viewing eye for an astronaut . . . employing infrared sensing and scanning techniques.

P-E **Electronic Components** are a part of the intricate controls of major computing and ground support systems . . . help make fire control, missile and rocket guidance systems super accurate.

Perkin-Elmer has one major objective: Wherever scientific measurements can be made — P-E instrumentation will provide the answer.

MISSILE . . . JOBS FOR PERKIN-ELMER

Qualified scientists and engineers interested in a career with Perkin-Elmer are invited to write the Director of Industrial Relations, Perkin-Elmer Corporation, 915 Main Avenue, Norwalk, Connecticut.

Perkin-Elmer
Corporation

1

+1

276

HOW? The figures are correct.

This is the "arithmetic" of the simplification that many engineers are buying from Fairchild today. The philosophy will interest you whether you are a customer or not.

It says, in effect, that two superior component types can eliminate the need for innumerable others of lesser performance. Most users of silicon diodes, for example, are now burdened with dozens or hundreds of separate specifications. Each type calls for paper work, testing, procurement and inventory. But why use up manpower perpetuating this confusion?

Two new Fairchild silicon diodes do in fact surpass all important specifications of 276 standard types and hundreds of other special types now in use. Their superior performance and reliability is achieved by the **planar process** and **surface passivation.** High yields to these two types are inherent in Fairchild's process. The result is low unit cost.

If you have circuits in the design stage today, consider the cost and performance advantages achieved by these technological breakthroughs. Or if you have circuits already in production, note Fairchild as a volume source of silicon diodes—both to advanced specifications and to established specifications, numerous as these latter may be.

In a similar way, Fairchild's silicon mesa and planar transistors are replacing older, less versatile types.

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SEMICONDUCTOR CORPORATION

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These symbols can be typed *by the very same* REMINGTON STANDARD® *and Electric Typewriters that type all your regular correspondence.* The typist herself makes the switch to scientific symbols—in mere *seconds!* Symbols are available for 10 sciences, including Biology, Chemistry, Electronics, Engineering, Law, Mathematics, Medicine, Physics. For full information, write Remington Rand, Room 1910, 315 Park Avenue South, New York 10, N. Y.

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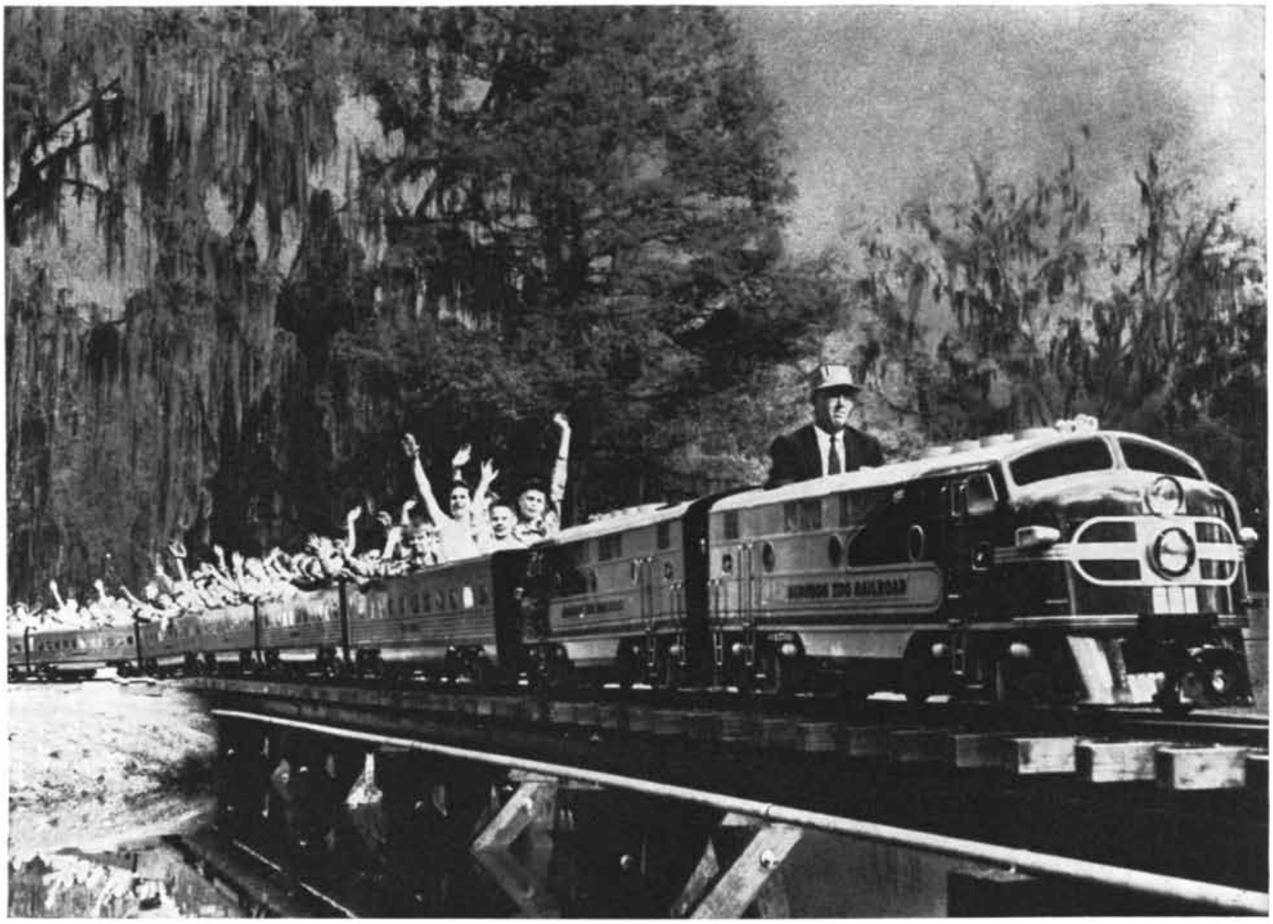


Unusual application of famous Bendix Electric Fuel Pump dependability is on miniature train operated at Audubon Park Zoo, New Orleans, La.

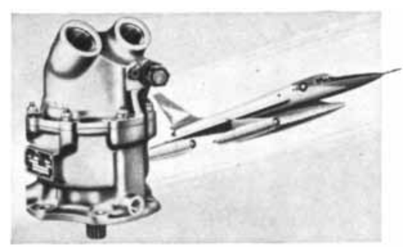
BENDIX PUMPS PUT "LIFE" INTO ALL KINDS OF VEHICLES

From miniature trains to supersonic missiles—from jet aircraft to mechanical cotton pickers—you'll find a wide variety of Bendix pumps helping vehicles of all kinds function more efficiently. Whether feeding fuel or hydraulic fluid, these pumps help put the "go" in transportation—much like the human heart pumps life through our bodies.

Hydraulic pumps, built by our Hamilton Division, Hamilton, Ohio, pump hydraulic fluid to actuate aircraft landing gear, flaps, ailerons, "elevators", and dive brakes. On missiles, they feed hydraulic fluid into devices that operate controls to keep the missile on course. These pumps deliver from 1 to 30 gallons of fluid a minute and operate at speeds up to 12,000 r.p.m. Yet, they combine light weight with ruggedness and power. On a typical bomber installation, four pumps—weighing about 16 pounds each—provide the equivalent of enough power to lift a 3000-lb. automobile 100 stories high in 36 seconds.

Other models include hydrocarbon and chemical gear fuel pumps, and pumps for fresh or sea water plus many other fluids. Bendix-Utica, Utica, N. Y., produces hydraulic control pumps for high temperature systems that require fully controlled and reversible fluid power.

The Bendix® Electric Fuel Pump, made by our Eclipse Machine Division, Elmira, N. Y., is used on sports cars, buses, boats, trucks, fire engines, and other such vehicles. By preventing vapor lock and providing even fuel flow, these pumps help make possible smooth engine power and performance. They're also used in connection with gasoline heaters, coffee makers, air conditioning systems, and other diverse equipment.



Bendix hydraulic pumps, measuring about 6″ in diameter and 8″ in length, meet the hydraulic needs of the Convair B-58—world's fastest bomber.

Our Bendix-Pacific Division at North Hollywood, Calif., contributes an aircraft hydraulic hand pump which serves as a power source for operating aircraft landing gear, flaps, etc.; for ground support equipment, and as a standby unit. Our Lakeshore Division, St. Joseph, Mich., manufactures constant pressure, piston-type pumps for self-propelled agricultural combines.

THE Bendix CORPORATION
Fisher Bldg., Detroit 2, Mich.

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Airco Gas *Experience* can supply unusual environments, such as minus 300° F

Want unusually low temperatures for testing, treating or storing? Airco nitrogen gas is what you're looking for. In the application above, for example, Airco nitrogen is just right for producing a frigid 300°F below zero — needed to test a missile component's ability to withstand the super-cold of outer space.

If, on the other hand, you want the temperature up to 6,000°F. for welding or cutting today's metals, Airco gases can serve you efficiently here also.

Airco Industrial Gases are doing highly specialized jobs in virtually every segment of industry. And they are at your service — backed by all of Airco's experience. Your nearest Airco office can provide the information you want.

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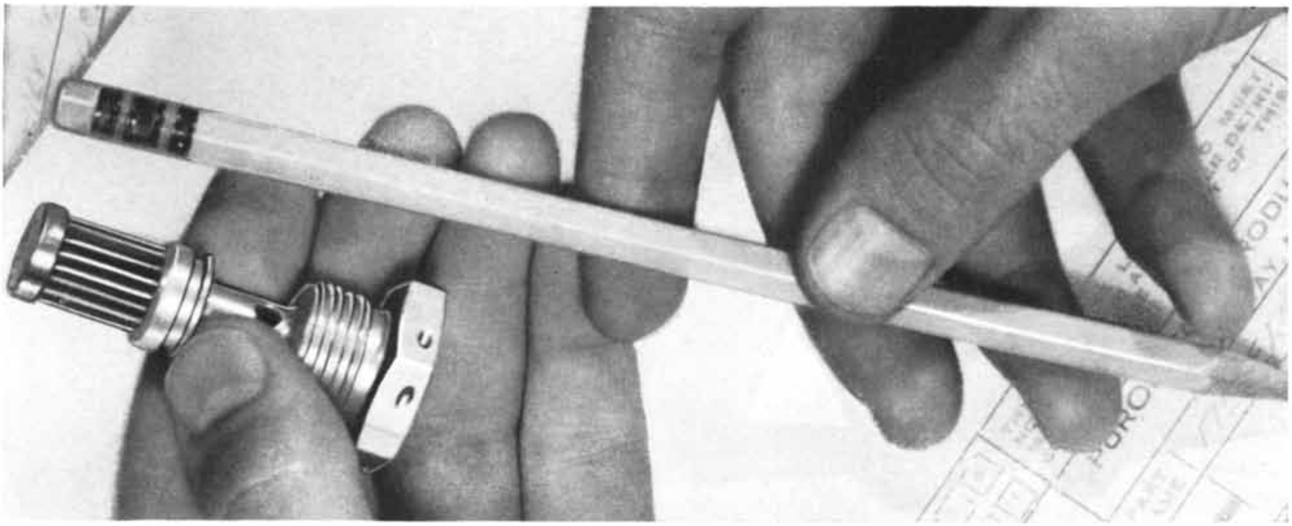

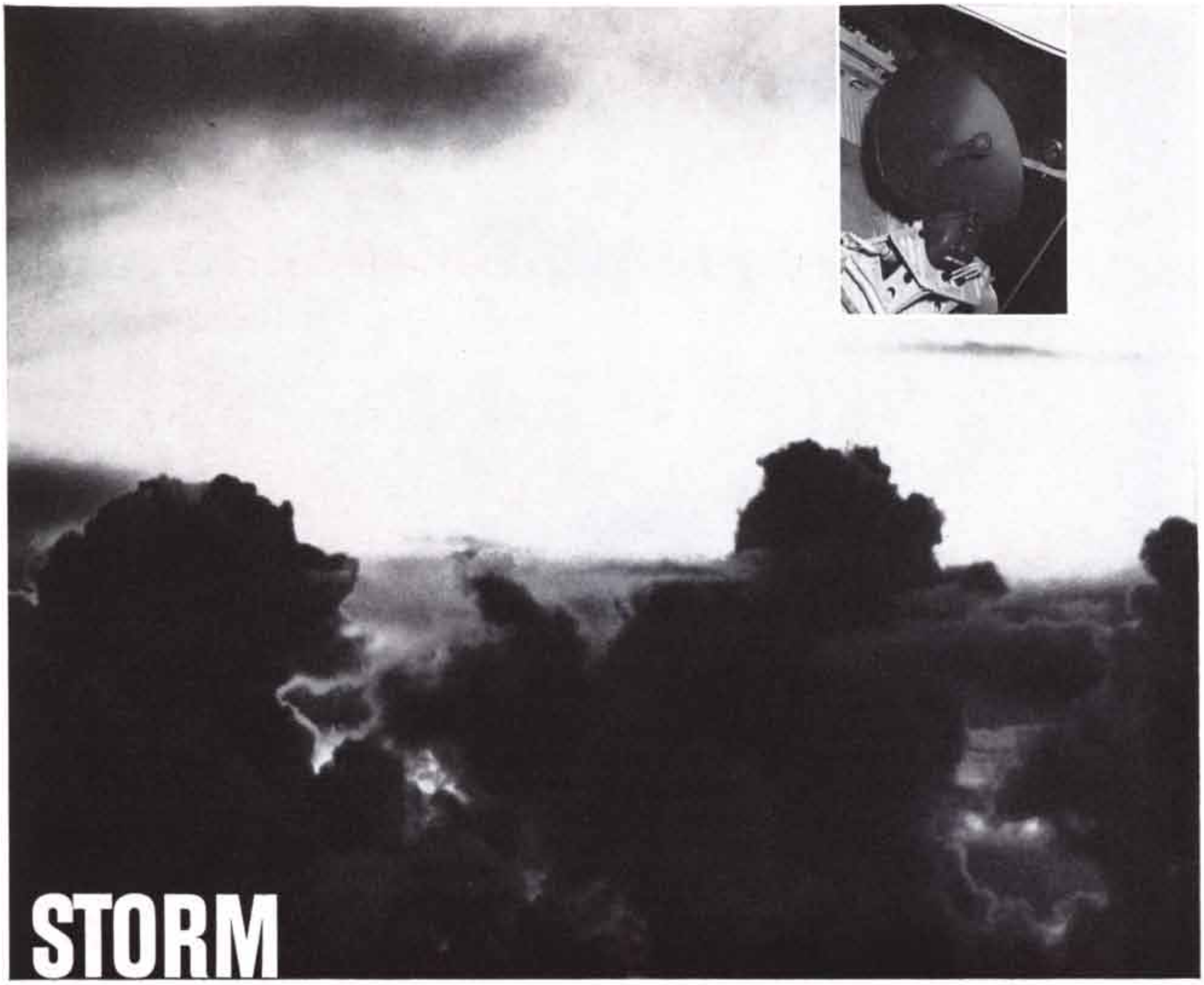

STORM WARNING... BY RADAR

Atmospheric turbulence has the characteristic of reflecting microwave signals, with the degree of reflection depending on the severity of the turbulence. Returned to the aircraft, this reflected radar warning is displayed in a manner that warns the pilot of the exact location and extent of the turbulence, enabling him to change his course and fly around dangerous storms. Since the radar display also shows him "holes" in storms where there is little or no turbulence, the pilot can choose a course that will result in maximum safety and minimum delay.

Commercial airlines use Varian klystron-equipped weather radar to assure the comfort and safety of passengers and the reduction to a minimum of storm hazards and delays. Photo above shows radar antenna inside the Radome nose of a United Air Lines plane.

In addition to the technical advantages of Varian klystrons to the equipment designer, their rugged mechanical construction and long life are vital benefits to the user. These characteristics are reasons why Varian has become the world's largest manufacturer of klystrons.

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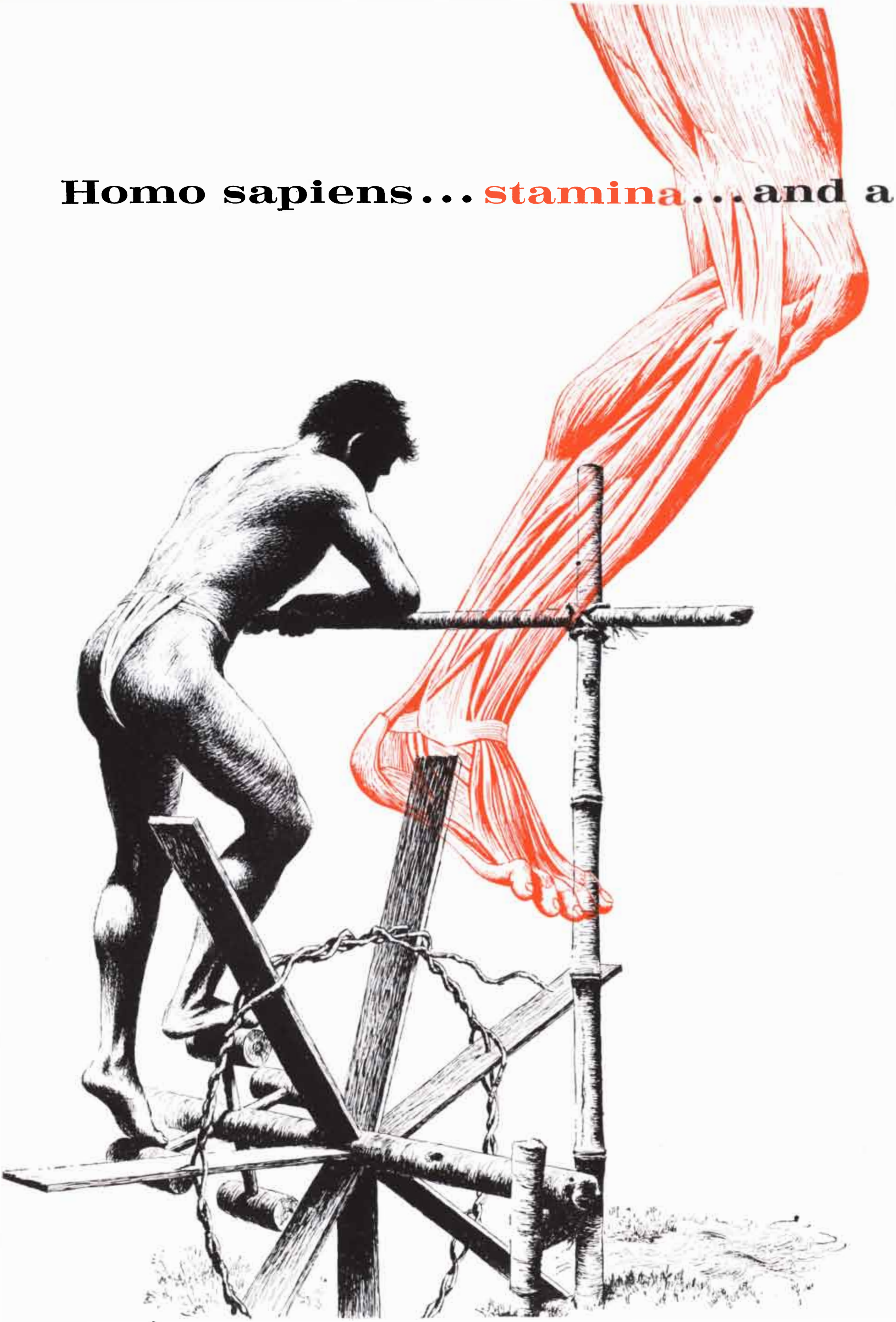


better power drive

In man's struggle to master his environment, he has invented machines to supplement the strength and stamina of his own muscle fibers.

Today, man boosts the efficiency of his machines with smaller, stronger V-belts, thanks to reinforcements of a synthetic fiber— "Dacron" polyester fiber.

The stamina of "Dacron" is remarkable. It combines all the advantages of dimensional stability, high initial modulus, good recovery and high resistance to shock loading (11 times that of wire). In everything from V-belt reinforcements to flexible pistons, "Dacron" continues to show new values.

Perhaps "Dacron" may prove valuable to you.

Du Pont's family of man-made fibers offers you exceptional versatility. Even now—tailored to specific needs or combined with other materials—fibers can outperform steel, wood or even lubricants. Our newly revised booklet, "Du Pont Fibers in Industry", supplies data on these fibers in industrial usage.

Please tell us your requirements. We'll be happy to provide any information or technical assistance regarding your use of Du Pont fibers for industry.

E. I. du Pont de Nemours & Co. (Inc.), 31K1 Centre Road Building, Wilmington 98, Delaware.

NYLON
"DACRON"* *polyester fiber*
"ORLON"* *acrylic fiber*
"TEFLON"* *TFE-fluorocarbon fiber*
"SUPER CORDURA"* *high tenacity rayon yarn*

DU PONT fibers for industry DU PONT REG. U. S. PAT. OFF.

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

*DU PONT'S REGISTERED TRADEMARKS

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

SEPTEMBER, 1910: "Marine construction is advancing by such leaps and bounds that we look within the near future to see the 750-foot warship and the 1,000-foot ocean liner. At present, apparently, the only influence which is limiting the size of ships is the question of harbor accommodations; there are but few channels and no drydocks that could accommodate vessels of this size. The launching last week of the British cruiser-battleship *Lion,* with a length of 660 feet and a displacement of 26,350 tons, is an advance for which there has been no parallel. Comparing the British armored cruiser *Cressy* of 1900 with the *Lion,* we find that the length has increased nearly 50 per cent and the displacement over 100 per cent. The same growth is noticeable in the merchant marine. It was predicted that the *Lusitania* and the *Mauretania,* with their maximum displacement of over 40,000 tons, and their over-all length of 790 feet, must stand for many years as marking the limit of practicable size. Nevertheless, two giant ships, the *Olympia* and the *Titanic,* which will be 860 feet in length, are being pushed to completion by the White Star Line. But the end is not yet; for the Hamburg-American Line has recently started work on a vessel that is to be 880 feet in length."

"The French production of aeroplanes amounts to about 800 machines, all told up to date, which represents a value of $2,500,000. The small Blériot sold at first for $2,000, but after its success in crossing the Channel the price was raised, and the latest type now costs from $3,000 to $5,000. The Farman machine now sells for $5,600, the Voisin for $4,600, the Antoinette for $5,000, the French Wright machine for $5,000 and the Sommer machine for $5,000."

"In a recent number of *Annals of Surgery* Dr. Alexis Carrel not only suggests the probability of intracardiac surgery, but even points out the technique of the various procedures which he believes will be developed in its performance. The real difficulty lies in the maintenance of the circulation, especially of the blood supply of the brain, during the slow and delicate operation. Dr. Carrel, however, has suggested a means of central and lateral diversion to overcome the difficulty. Dr. Carrel insists that none of the procedures he recommends has as yet attained the technical perfection which warrants application to the human being."

"The transatlantic record to the westward has again been reduced by the Cunard liner *Mauretania.* Leaving Queenstown on Saturday, the ship passed Daunt's Rock at 10:08 Sunday morning, September 11th, and reached the Ambrose Channel lightship at 3:49 P.M. the following Thursday, September 15th. The total time of the passage was four days 10 hours and 41 minutes, which is 10 minutes less than the record established by the same vessel last season. The distance is 2,780 miles, and the average speed is 26.06 knots."

"Thomas A. Edison has invented what he calls a kinetophone, which is a combination of his kinetoscope and his phonograph. It is his object to produce pictures which talk. He recently gave an exhibition at his West Orange laboratories, which was very impressive."

"A Pennsylvania inventor has recently come to the aid of the long-suffering suburbanite with a lawn mower which is self-propelled, and needs but to be guided over the turf. The motor attachment may be mounted to a lawn mower of standard make, and consists of a framework secured to the handle of the mower and to the brackets in which the rear roller is mounted. Suspended from the framework is a gasoline motor that is connected with chain and sprocket gearing to a pinion which drives the gear mounted on the main shaft of the mower."

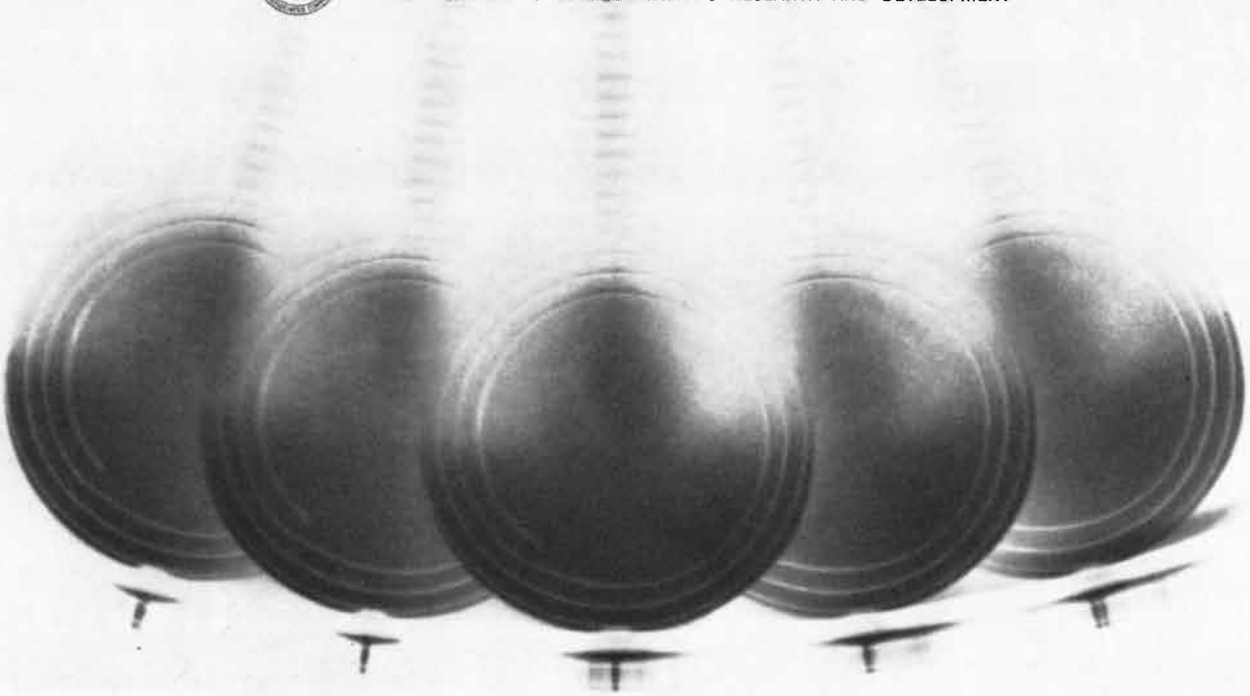
Scientific American.

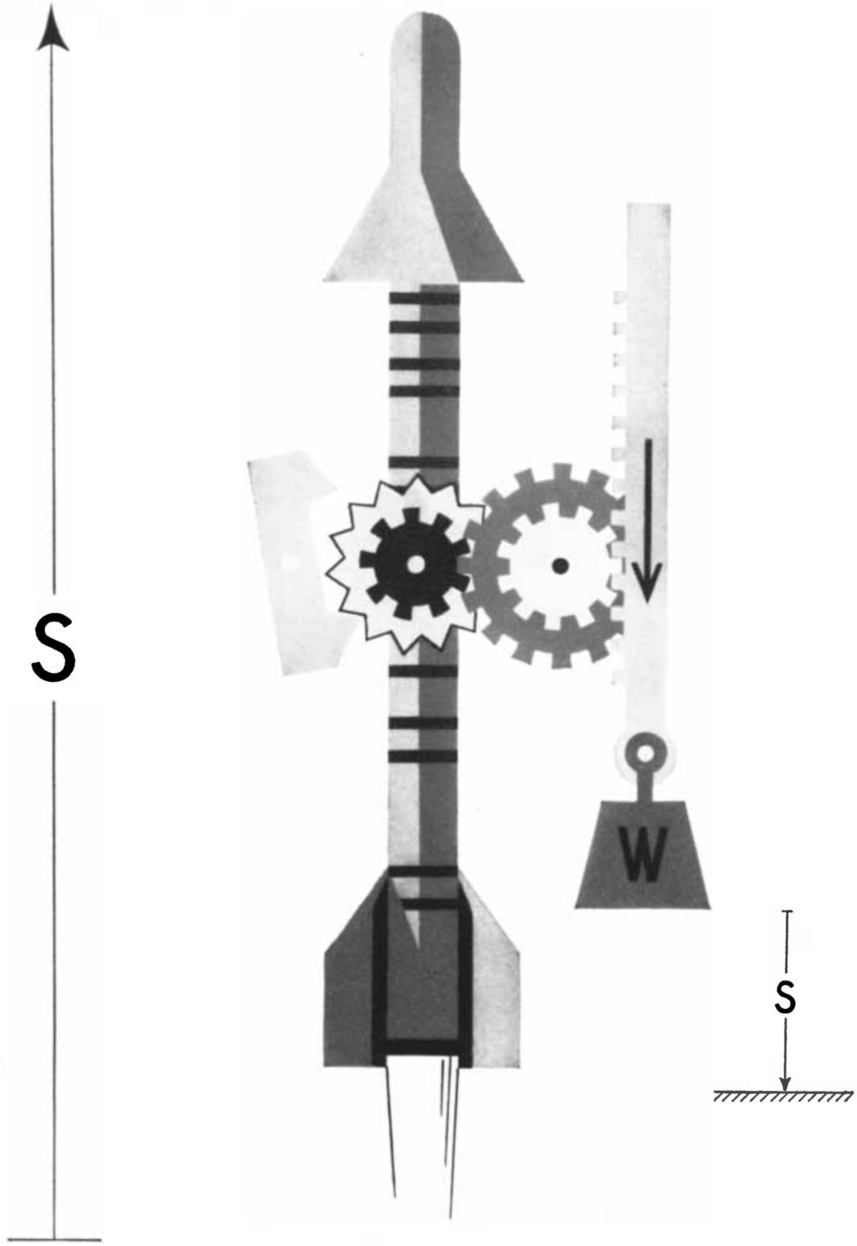
SEPTEMBER, 1860: "It seems to be the general opinion that gutta-percha is absolutely worthless for the insulating of submarine telegraph cables, while India rubber, from experiments extending over 20 years, promises to answer every requirement. The Atlantic cable, besides the use of gutta-percha as an insulating agent, had also another fatal defect. The spiral form of the external wires permitted the coating to stretch under a strain, and this almost completely destroyed its value. The great blunder in the conduct of the Atlantic telegraph enterprise was the childish haste with which it was hurried through; not permitting a proper test of the various new plans required. This blunder will now be avoided, and it is probable that the next effort will be successful."

"Of all inventions of which it is possible to conceive in the future, there is none which so captivates the imagination as that of a flying machine. The power of rising up into the air, and rushing in any direction desired at the rate of a mile or more in a minute, is a power for which mankind would be willing to pay very liberally. What a luxurious mode of locomotion! What little attention this subject has heretofore received from inventors has been almost wholly confined to two directions: flying by muscular power and the guidance of balloons. Both of these we have been accustomed to regard as impracticable. The thing that is really wanted is a machine driven by some natural power, so that the flyer may ride at his ease. For this purpose, we must have a new gas, electric or chemical engine. The simplest of all conceivable flying machines would be a cylinder blowing out gas in the rear, and driving itself along on the principle of the rocket. We might add several other hints to inventors who desire to enter on this enticing field; but we will conclude with only one more. The newly discovered metal aluminum, from its extraordinary combination of lightness and strength, is the proper material for flying machines."

"The American steamship *Vanderbilt* has proved herself to be the fastest sailer afloat. She sailed from New York July 28, at 2:30 P.M., and arrived at Southampton Aug. 6, at midnight. Allowing five hours for the difference in time in sailing eastward, she made the trip in nine days and four hours."

"Before referees, a suit has been brought by F. O. J. Smith against Professor Morse, to recover five sixteenths of the money received by Professor Morse from the different governments of Europe for the invention of the telegraph. The parties have been connected together in the telegraph business for some 20 years, and some time since a settlement was had between them, when Mr. Smith received $300,000, and here matters in dispute were left open for suit or reference, of which this is one."





Bulova escapement used as an integrating accelerometer

Bulova's unusually creative teams of scientists and engineers play an ever increasing role in the vanguard of precision design and development. Consider the nature of a Bulova escapement; it's generally employed as a second-order integrating accelerometer. However, the basic mechanism lends itself equally well to rotational motion of unbalanced rotors in an accelerating field.

The drawing above shows an inertial element, or weight, coupled to a runaway escapement by a rack. A safe-arm latch locks the system until missile launch. Under acceleration the escapement will delay the weight from moving through its stroke, *s*, according to the following:

(1.) $$t = \sqrt{\frac{K}{ag}}$$

Where t is the time for the weight, W, to traverse its stroke, s, under an acceleration a, K is the mechanism constant which takes into account the gear ratio; the moment of inertia of the system as reflected at the pallet wheel; and the number of pallet cycles involved during stroke s.

If the acceleration is constant, the change in distance of the missile during t is

$$S = \frac{1}{2}agt^2$$

or

(2.) $$t = \sqrt{\frac{2S}{ag}}$$

Equating (1) and (2)

$$\sqrt{\frac{2S}{ag}} = \sqrt{\frac{K}{ag}} \qquad S = 2K$$

It is thus evident that, for a given escapement with a given stroke, the distance integrated is constant, and is independent of acceleration.

Bulova developments in the field of time measurement are particularly significant because they advance the state-of-the-art with existing systems and elements . . . with existing components of proven reliability and accuracy. But, continuing study of new concepts keeps Bulova systems years ahead—ready to meet the future needs of both the military and industry.

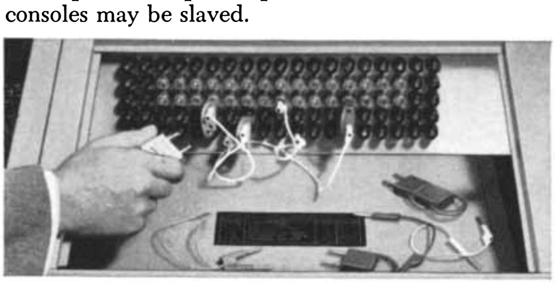
BULOVA

Research & Development Laboratories, Inc.
62-10 Woodside Avenue, Woodside 77, N. Y.

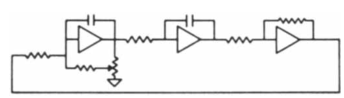
Did you ever use a computer as versatile as the DONNER 3100?

The Donner 3100 isn't for people who merely wish to push buttons. It is a medium sized, high accuracy computer, simple to operate, but designed so it doesn't horsecollar the operator. In its class (20 to 100 amplifiers) it is the most versatile analog computer. Two big reasons for this are the 3100's *uncommitted amplifiers* and its *simulation board,* an auxiliary patchbay electrically connected to the main removable problem board. Here's what they do:

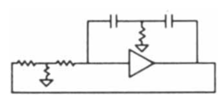
Uncommitted Amplifiers. The 3100's amplifiers are not already wired as summers or integrators. The operator patches his resistors and capacitors to the amplifier. Obviously, he is not limited to using computing components with fixed values. If he wants to use only two components per amplifier, all the rest are free. Depending upon your needs, the 3100 can be supplied with up to 50 amplifiers per console and two or more consoles may be slaved.



The Simulation Board. Here the operator can plug in a wide variety of components—resistors, capacitors, pots and diodes. He can synthesize (a) complex input and feedback networks for amplifiers, (b) complex resistor-diode limiting circuits and (c) resistor-capacitor-inductor filter networks. Programming these circuits on the simulation board is far simpler and saves amplifiers. For example, a mass-spring system is oscillatory and usually needs three amplifiers to simulate it:



But this clever little circuit does the same thing:



You see, we have eliminated two amplifiers by using the simulation board.

Speaking of economy, **$13,995** buys a Donner 3100 with 30 stabilized amplifiers and 55 potentiometers. A full line of nonlinear and accessory equipment is available. Free instruction on computer theory and operation is included.

Get More Facts—*Contact your Donner engineering representative for Data File 310, or write directly to Dept. 99.*

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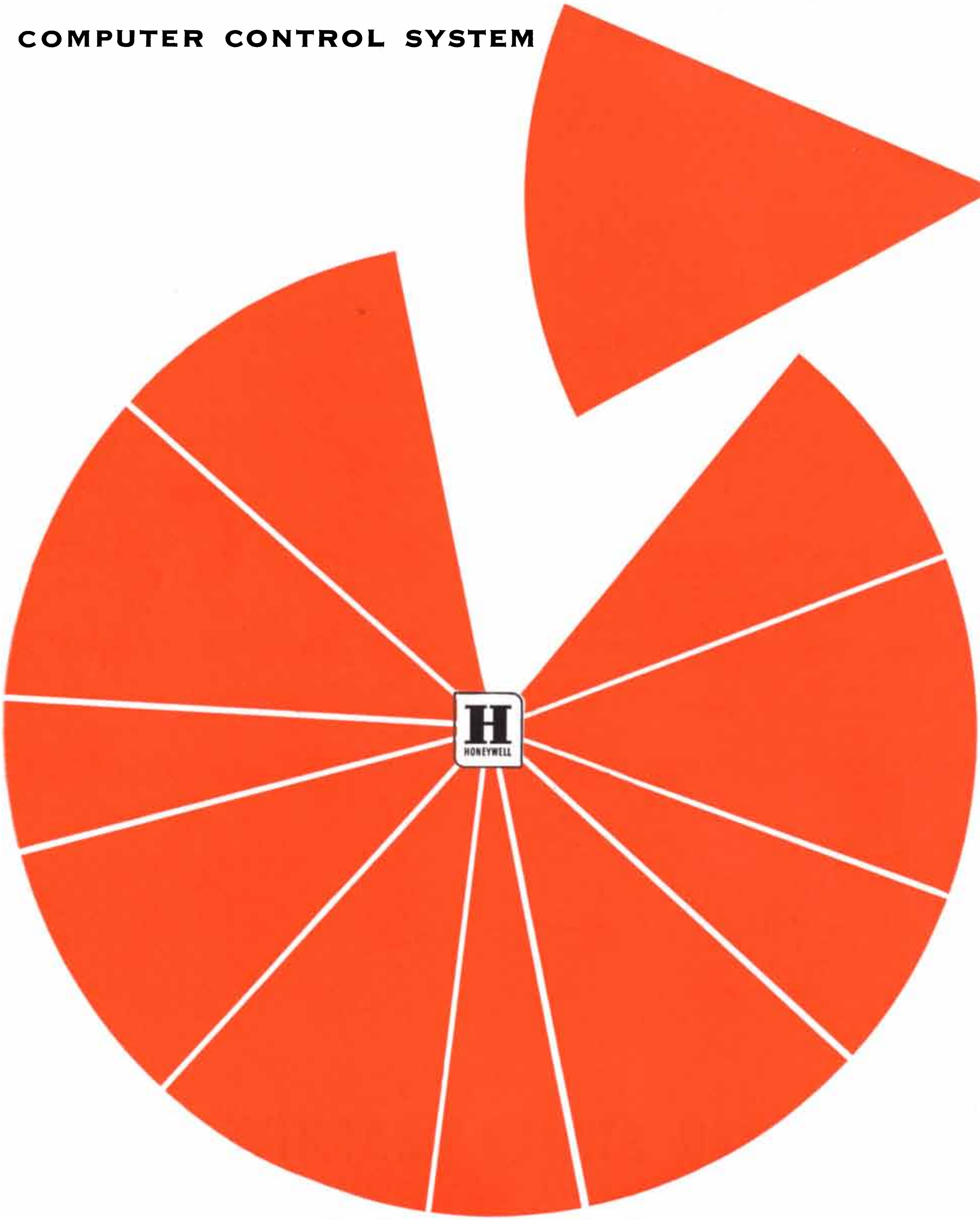
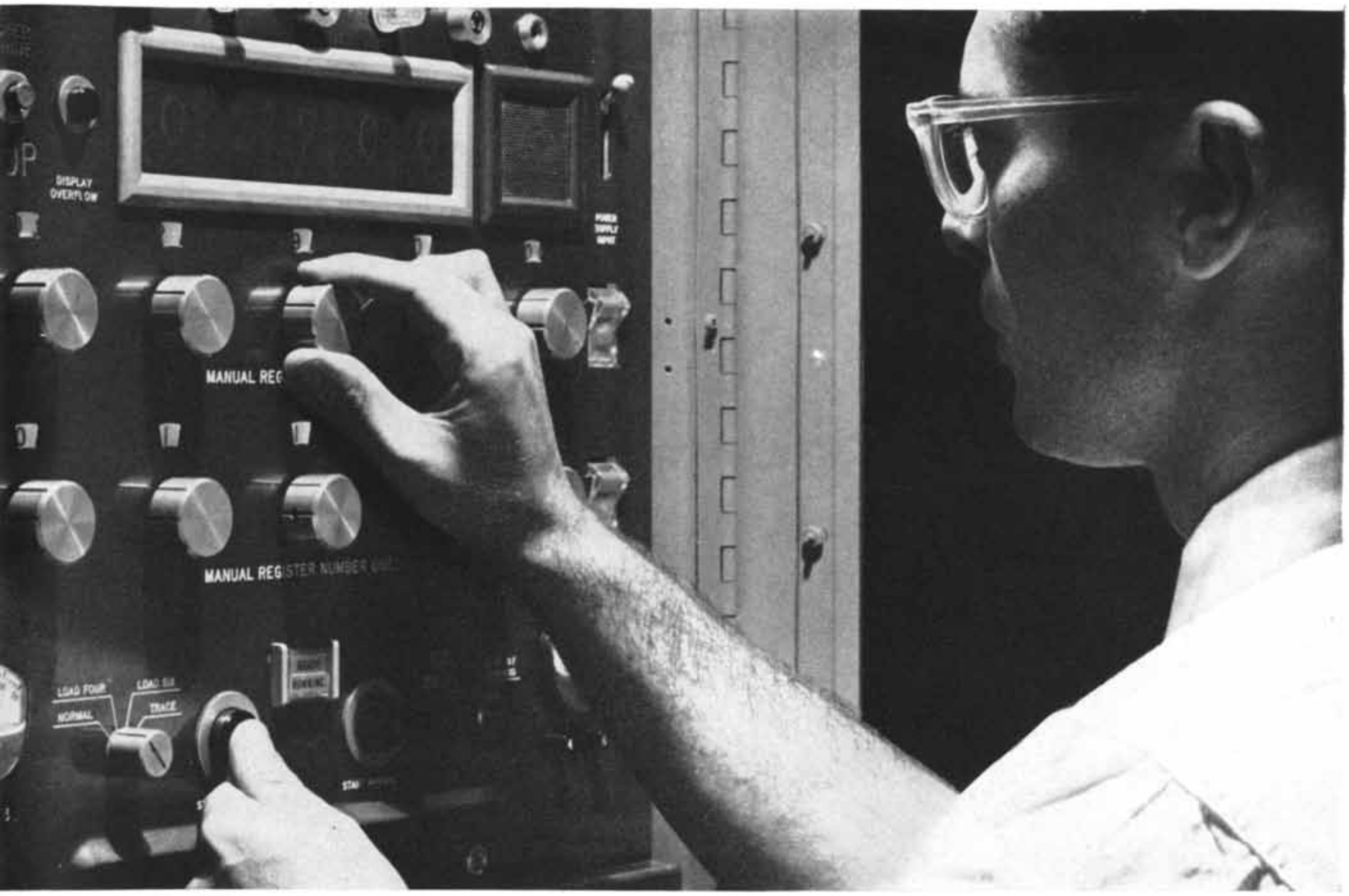
29 A

NEW HONEYWELL 290 INDUSTRIAL DIGITAL COMPUTER

. . . HEART OF THE FIRST COMPLETELY INTEGRATED

COMPUTER CONTROL SYSTEM





Single-Source Responsibility. Now you can get the first truly complete computer control package produced by a single manufacturer. The new, all-solid-state Honeywell 290 Industrial Digital Computer rounds out Honeywell's broad line of instrumentation, and enables you to specify an all-Honeywell process control system. That means you're protected by single-source responsibility . . . from primary elements to final controls, from initial concept through maintenance.

High Speed plus Reliability. This new computer is the most powerful in its field. Typical operation rates: 8,000 additions, 1,250 multiplications, or 400 square root extractions per second. This high-speed computing of currently pertinent data gives you precise process control. Simplified programming adapts the computer easily to process changes. All-solid-state design and extensive system self-checks are engineered into every circuit and every unit of the computer.

Application Experience plus Computer Know-How. With the addition of the Honeywell 290 computer to the world's most extensive line of measuring and control equipment, Honeywell systems engineers now have the tools to implement all applications including those requiring computer control.

Take advantage of Honeywell's 75 years of experience in industrial process control. Get the advantage of having your entire system under Honeywell's overall responsibility.

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Honeywell

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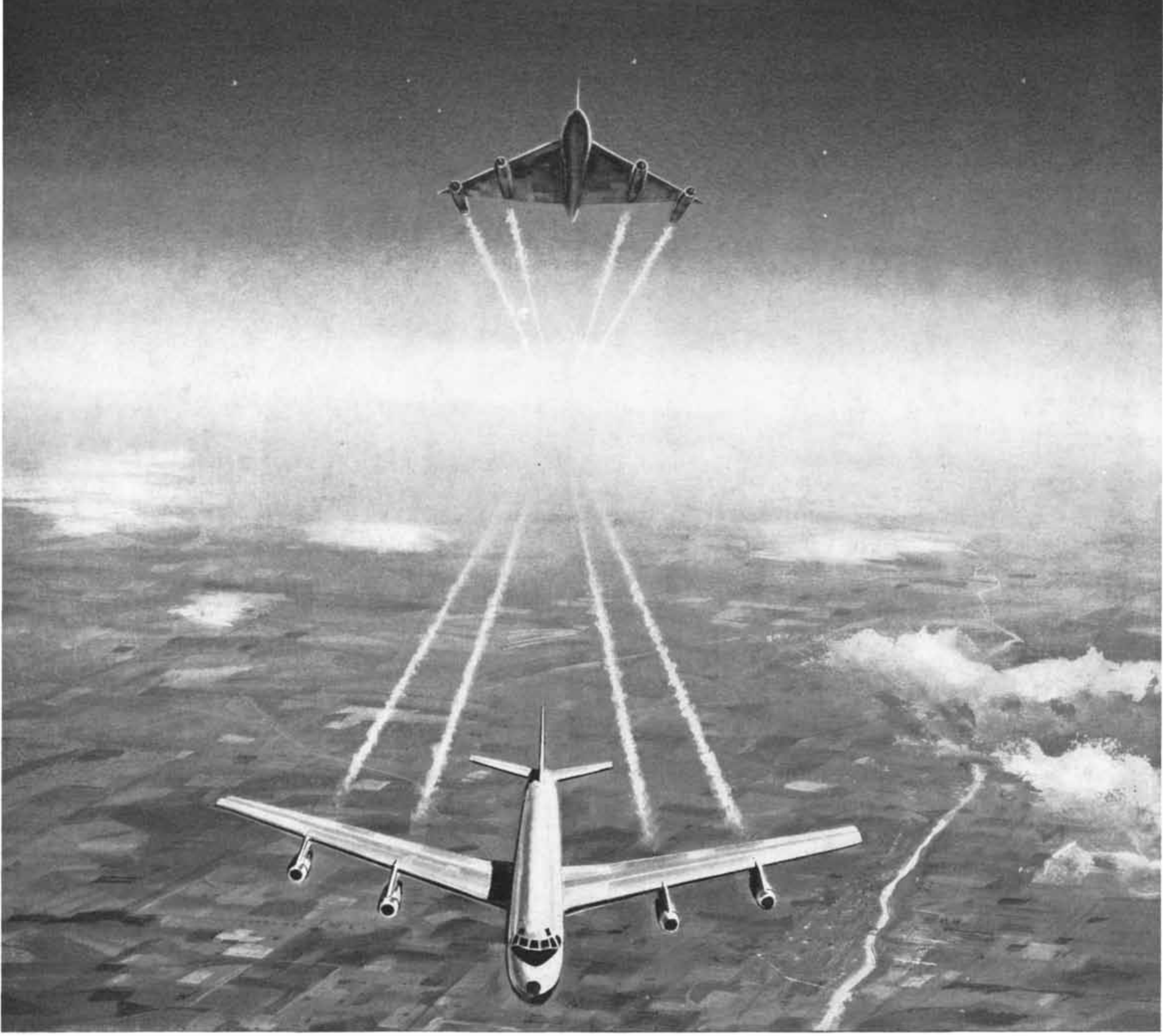
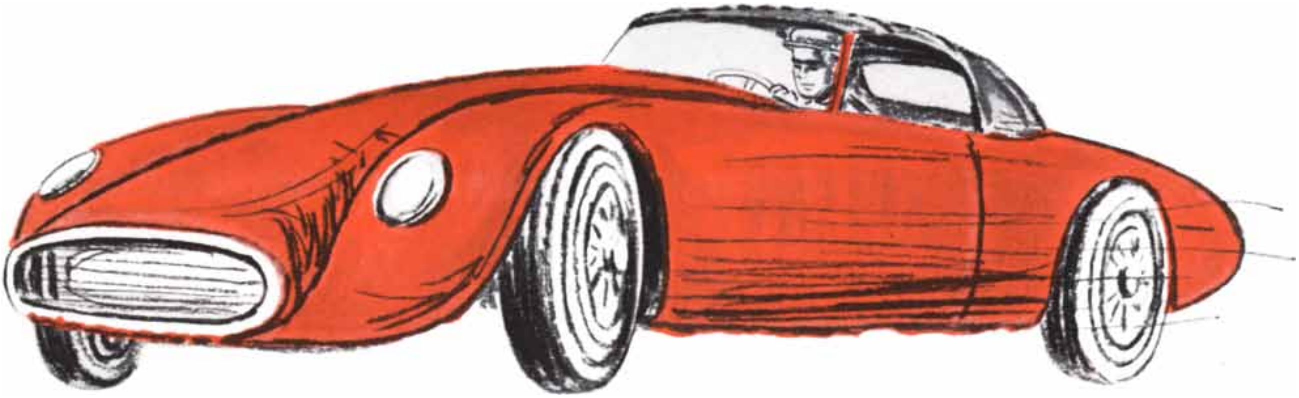
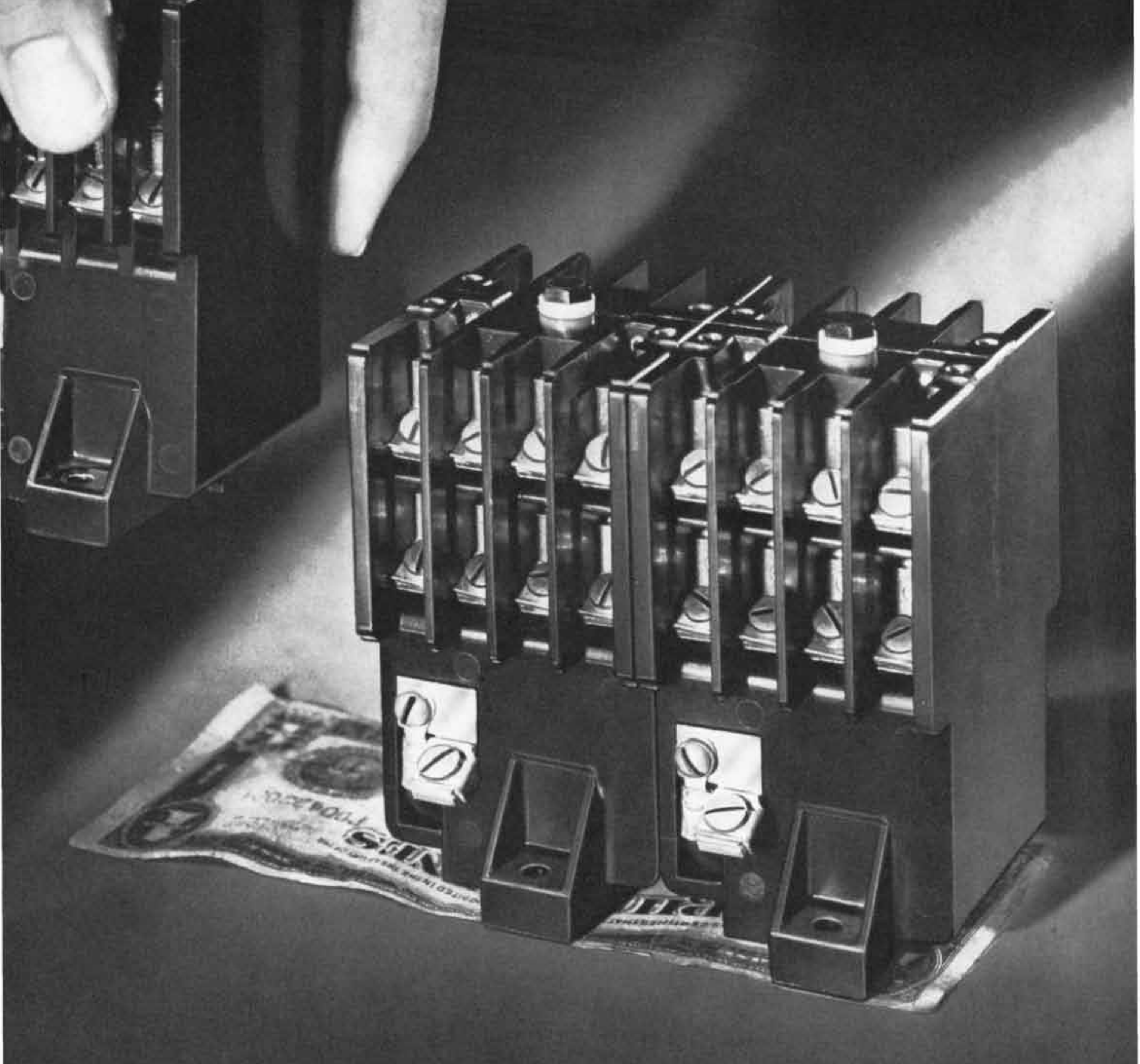
SINCE 1885

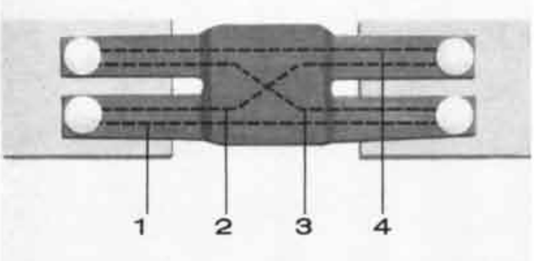






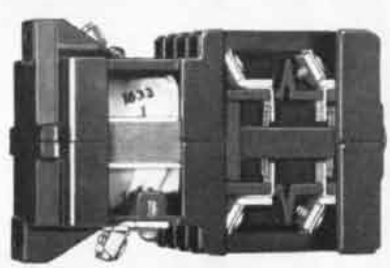
Another Cutler-Hammer first! Up to 24 poles in an area less than the size of a dollar bill.

New contact reliability. Parallel bifurcated contacts, which allow four current paths instead of one, provide infinitely greater circuit reliability . . . liberally designed so any current path carries full relay rating.



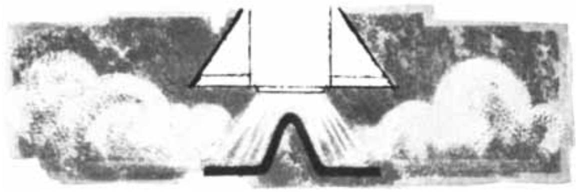
At last! "Mechanical memory" latch as reliable as the relay itself! No adjustment ever needed. Add latch at any time.

New simplified design! Cutaway view shows basic simplicity. Coil vacuum impregnated to resist damage from humidity, vibration, electrical stress. Terminals can be screw or spade type.

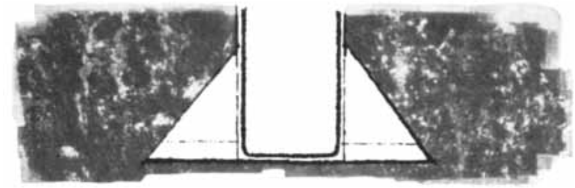


Need a **NONCRITICAL** *material to solve a* **CRITICAL** *heat problem?*

Consider these Goodyear Aircraft capabilities in the field of high-temperature laminates—

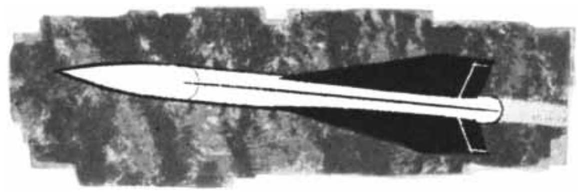


HERE'S AN INEXPENSIVE BLAST DEFLECTOR—made of reinforced plastic—which can withstand the direct blast of a rocket engine. Goodyear Aircraft stands ready to design and fabricate economical, reusable blast deflectors to your specific requirement.

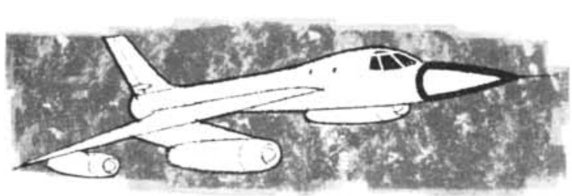


CRYOGENIC FUEL TANK INSULATION by Goodyear Aircraft is less than ¼-inch thick, yet has proved its ability to prevent "boil off" of liquid gaseous rocket fuels, such as liquid nitrogen and liquid hydrogen. Use of a plastic laminate for this purpose can mean substantial weight, space and cost savings.

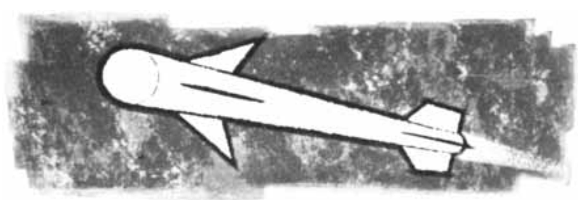
NOSE CONES FOR GLIDE RE-ENTRY VEHICLES can be produced at Goodyear Aircraft to a wide range of specifications. The reason: extensive experience with ablative and thermal-resistant techniques. Do you need a lightweight nose cone material that can withstand 2000° to 2500° for an hour or more? Whatever your re-entry requirement, a specially compounded high-temperature laminate may well be the answer.



LEADING EDGES OF MISSILES or aircraft can be protected against prolonged high-temperature exposure by plastic laminate-coverings which conform to the metal structure. Reinforced plastic laminates by Goodyear Aircraft can also be used for jet vanes, rocket nozzles, fins and other miscellaneous missile components.



RADOMES FOR AIRCRAFT which operate at Mach III and above have been produced at Goodyear Aircraft. Goodyear Aircraft has a vast background in radome engineering and manufacturing for both the solid and honeycombed layered constructions.



"PLASTIC" MISSILES—built by Goodyear Aircraft—could utilize a variety of plastic laminates and fabrication techniques. Advantages of such all-plastic components: no use of critical material, high strength-to-weight ratio, low cost in mass production, rust- and corrosion-resistant.

Your inquiry is invited *regarding these specific capabilities—or any requirement calling for a noncritical, high-strength material which must retain its properties under the most demanding heat and stress conditions. WRITE: Goodyear Aircraft Corporation, Dept. 916OU, Akron 15, Ohio.*

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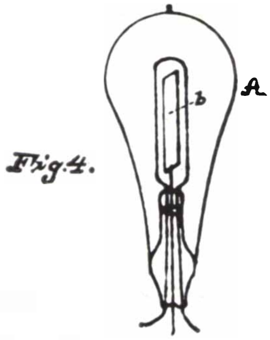

Patent No. 307,031,
October 21, 1884

"I have discovered that if a conducting substance is interposed anywhere in the vacuous space within the globe of an incandescent electric lamp, and said conducting substance is connected outside the lamp with one terminal, preferably the positive one of the incandescent conductor, a portion of the current will, when the lamp is in operation, pass through the shunt-circuit thus formed, which shunt includes a portion of the vacuous space within the lamp." THOMAS A. EDISON.

Evolution of the electron tube

Beginnings are often misty, the significance of discovery obscure and, initially, the march of progress slow. So it was with electron tubes. Edison knew he had something strange on his hands but he could not begin to realize the incredible epoch of progress the "Edison Effect" was to generate. In fact, soon after his discovery his interests were diverted to other enterprises. But in the next two decades other men of vision, notably Fleming and DeForest, were struck by the far-reaching implications of thermionic emission. Then at the turn of the century, DeForest invented the three-element vacuum tube, and the floodgates opened through which spilled the "miracle" era of electronics.

Quickly, pioneering industrial organizations like Tung-Sol turned their research and manufacturing skills to tube development. Advance followed advance in whirlwind fashion. New tube types evolved in rapid succession, sparking revolutionary changes in man's communication technology. Radio, radar, television, computers, missile and satellite telemetry all stem from this unparalleled cavalcade of progress. In this still unfolding drama of electron tube evolution Tung-Sol plays a commanding role. Tung-Sol Electric Inc., Newark 4, N. J.

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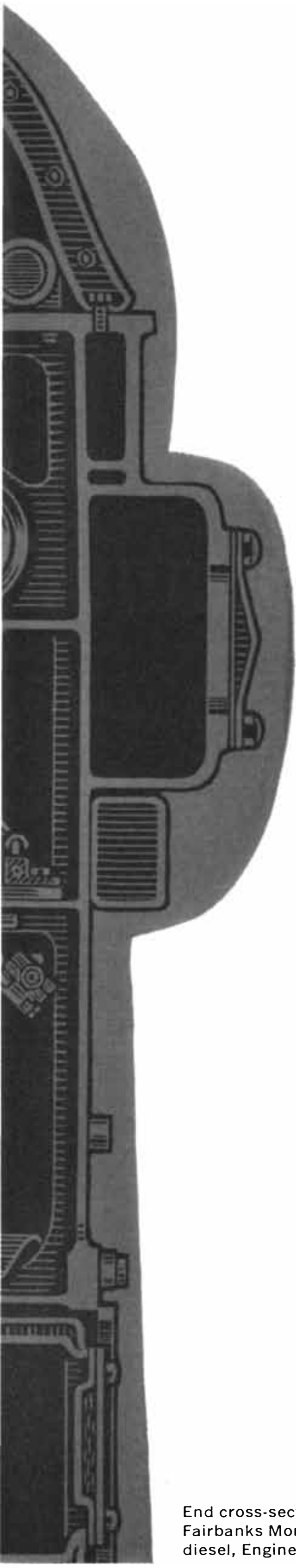

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THE AUTHORS

SHERWOOD L. WASHBURN ("Tools and Human Evolution") is professor of anthropology at the University of California. He was born in Cambridge, Mass., in 1911, attended the Groton School and acquired his B.A. at Harvard University in 1935 and his Ph.D. in anthropology from the same institution in 1940. He taught anatomy at Columbia University from 1939 to 1942, at which time he joined the department of anthropology at the University of Chicago. Washburn became a member of the California faculty last year. He is a past president of the American Association of Physical Anthropologists, and since 1955 he has been editor of the Association's journal. He wishes to thank Raymond A. Dart, L. S. B. Leakey and J. T. Robinson for their kindness in allowing him to examine the man-ape fossils described in the present article.

MARSHALL D. SAHLINS ("The Origin of Society") is assistant professor of anthropology at the University of Michigan. He was born in Chicago, Ill., 30 years ago and acquired his B.A. and M.A. at Michigan in 1951 and 1952, respectively. He received his Ph.D. in 1954 from Columbia University, where he also lectured before joining the Michigan faculty. Sahlins is the author of *Social Stratification in Polynesia*, published in 1958, and is co-editor and co-author of *Evolution and Culture*, which was published this year. He is currently engaged in research on the relationship between economics and polity in primitive societies, under a three-year grant awarded by the Social Science Research Council.

CHARLES F. HOCKETT ("The Origin of Speech") is professor of linguistics and anthropology at Cornell University. A native of Columbus, Ohio, he took his B.A. and M.A. in ancient history at Ohio State University in 1936 and his Ph.D. in anthropology at Yale University in 1939. After serving four years in the Army in World War II, during which time he traveled on every continent except Europe, he went to Cornell in 1946. Hockett's work on the origin of language described in the present article began in 1955, when he was at the Center for Advanced Study in the Behavioral Sciences at Stanford, Calif. There, he says, "I began to learn what zoologists, animal behavior students, ethologists and paleontologists had discovered."

WILLIAM W. HOWELLS ("The Distribution of Man"), professor of anthropology at Harvard University, is a grandson of the writer and critic William Dean Howells. He acquired his degrees at Harvard, receiving a Ph.D. in 1934. From 1939 to 1954 he taught at the University of Wisconsin, except for three years as a lieutenant in the Office of Naval Intelligence during World War II. He joined the faculty of Harvard in 1954. Howells is a past president of the American Anthropological Association and a past editor of the *American Journal of Physical Anthropology*. He is the author of *Mankind So Far*, and *Mankind in the Making*, which is to be published this fall.

ROBERT J. BRAIDWOOD ("The Agricultural Revolution") is professor in the Oriental Institute and in the department of anthropology at the University of Chicago. He was born in Detroit, Mich., in 1907 and acquired his B.A. and M.A. at the University of Michigan in 1932 and 1933, respectively. He obtained a Ph.D. in archeology at Chicago in 1942, joining the faculty there two years later. Since 1947 he has been field director of a series of archeological expeditions to Iraq and Iran, the results of which are discussed in his article for this issue. This work has been partly financed by the National Science Foundation, the American Philosophical Society and the Wenner-Gren Foundation for Anthropological Research.

ROBERT M. ADAMS ("The Origin of Cities") is assistant professor of anthropology and Oriental Institute research associate at the University of Chicago. He was born in Chicago, Ill., 34 years ago and served in the Navy from 1944 to 1946. He obtained his degrees at Chicago, receiving a Ph.D. in anthropology in 1956. His first field work was done in collaboration with Robert J. Braidwood on an archeological expedition to Iraq in 1950 and 1951. Since then his work has taken him to Yucatán, Mexico and the Near East. He hopes to return to Iraq in the fall to continue archeological reconnaissance in connection with modern agricultural-development programs.

HERBERT BUTTERFIELD ("The Scientific Revolution") is professor of modern history at the University of Cambridge. He took his degree at Cambridge and was elected a Fellow of Peterhouse at the same institution in 1923. He became Master of Peterhouse in 1955 and vice chancellor of the University in 1959. His writings include books on Christianity, international affairs and the history of science. One of his best-known books is *The Origins of Modern Science: 1300-1800*. At present he is writing a one-volume *Cambridge Shorter Modern History* and a work entitled *The History of Historiography*.

EDWARD S. DEEVEY, JR. ("The Human Population") is professor of biology and director of the Geochronometric Laboratory at Yale University. Born in Albany, N.Y., in 1914, he attended Yale, where he obtained his B.A. in 1934 and his Ph.D. in 1938. He was an instructor at Rice Institute for four years, and a research associate at the Woods Hole Oceanographic Institution for three, before he joined the faculty of Yale in 1946. Of the several articles he has published in SCIENTIFIC AMERICAN, the most recent was "Bogs" (October, 1958). "My own dirty-hands research," he says, "is still in Pleistocene ecology," and he is planning field trips to Central America and to Wyoming and Utah during the coming year to continue his study of lake sediments.

THEODOSIUS DOBZHANSKY ("The Present Evolution of Man"), DaCosta Professor of Zoology at Columbia University, has done research in genetics and biological evolution on every continent except Antarctica. He was born in Nemirov, Russia, in 1900 and took his degree at Kiev University in 1921. From 1921 to 1924 he lectured on zoology at the Polytechnic Institute in Kiev. After three years as assistant professor of genetics at Leningrad State University, he came to the U. S. in 1927. In 1929 he joined the faculty of the California Institute of Technology. He has been at Columbia since 1940. Dobzhansky has just completed a year of research, on the evolutionary genetics of Drosophila populations, at the University of Sydney in Australia. This is his fourth article for SCIENTIFIC AMERICAN.

C. P. SNOW, who in this issue reviews *The Western Intellectual Tradition: From Leonardo to Hegel*, by J. Bronowski and Bruce Mazlish, is a noted British novelist. He is best known for his series of novels entitled *Strangers and Brothers*. The most recent of these novels, *The Affair*, was published early this year. He will spend the coming fall semester at the University of California as Regents' Professor of English.

ANACONDA CONDENSER AND HEAT EXCHANGER CLINIC

"Cupralum," lead-surfaced Anaconda copper tube, offers practical answers to some tough corrosion problems

If you'd be interested in more compact, more economical heat transfer units for handling corrosive liquors — sulfuric, chromic, phosphoric acids, sulfites, sulfates, alum, and the like — you should know about Cupralum*. Cupralum, a product of Knapp Mills, Inc., is Anaconda copper or copper-alloy tube to which a uniform, dense-structured, extruded chemical lead surfacing has been metallurgically bonded.

Alfred P. Knapp, chairman, Knapp Mills, Inc., explains to visitors how his company's patented drawing process metallurgically bonds lead surfacing to copper tube.

THE OUTSIDE lead surface, which may be from 1/8″ to 1/2″ thick, resists concentrations of acids—of sulfuric acid, for example, up to about 85% and up to 428 F. Being bonded to the copper, it expands and contracts with the copper during temperature cycling. Without the metallurgical bond, the lead would creep and eventually fail—an inherent weakness of all-lead tubing.

Two U-bend Cupralum tube bundles like this are used in a Ferrolum (lead-surfaced steel) separator tower to boil off ammonia from a urea carbonate ammonia solution—in the production of urea fertilizer. Anaconda copper tube core 1″ O.D., 12 gauge, handles 150-lb. steam. Lead surface is 3/16 inch thick. Separator tower operates at 145 C (293 F) and 240 psi.

THE COPPER or copper-alloy tube inside provides strength to make Cupralum self-supporting — and to stand steam pressures up to 150 psi in standard wall thicknesses offered. It also provides its high corrosion resistance internally to cooling waters, steam, and refrigerants.

Most important, copper offers its high heat transfer rate. Because of the metallurgical bond with the lead, the over-all heat transfer rate of Cupralum is high—higher than all-lead tube and higher than that of iron and steel.

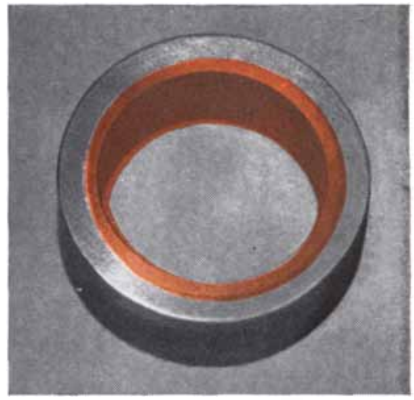
THE NET RESULT is that a given heat transfer job can be done with fewer square feet of surface — for a more compact unit. Or it is possible to get increased capacity in present existing space.

Lead surfacing removed from ends of Cupralum tubes preparatory to insertion in lead-clad steel tube sheet. Tube ends are usually rolled, but for severe thermal cycling service, may be brazed to outer steel face of tube sheet.

In many cases, the first cost of the coil is lower. Usually this is true where higher steam pressures than those previously used are available—or where expensive, hard-to-fabricate alloys have been used. Improvement of the heating or cooling cycle is another source of savings. Under any circumstances, a long operating life and easy maintenance provide over-all economy.

NUCLEONIC APPLICATIONS. Cupralum with a thicker surfacing of lead is being used increasingly in the nuclear industry. For gamma shields that must be cooled, Cupralum coils are built in to provide efficient heat transfer from the shield to the cooling medium.

Where radioactive liquors and spent resin discharge from demineralizers must be conveyed through process piping into process vessels for concentrating the radioactive solution, Cupralum piping prevents the escape of gamma radiation. In nuclear applications, the lead surfacing may be 1″ to 8″ thick.



Cutaway section of Cupralum tube. It is produced in 20′ lengths or in long continuous coils —from 40′ to 100′ depending on diameter. It is easy to bend and fabricate. Reliable jointing techniques have been developed.

Lead surfaces of Cupralum tubes and of tube sheet are fused by lead-to-lead welding. Then an extra thickness of lead is applied at the joint for extra protection.

FOR MORE INFORMATION. For detailed data on Cupralum, write Knapp Mills, Inc., Wilmington, Del. Or see your Anaconda representative, who can also provide data on the full line of Anaconda copper and copper-alloy tubes—arrange for technical assistance in meeting special corrosion and heat transfer problems. The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 6071

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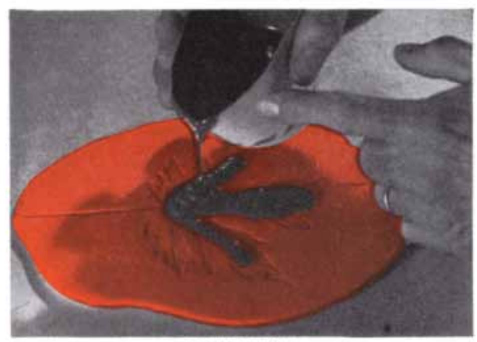

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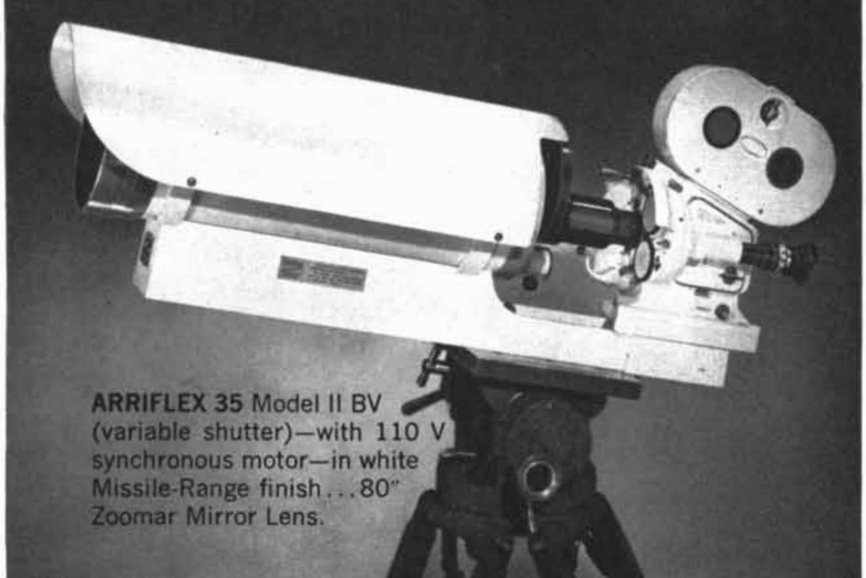

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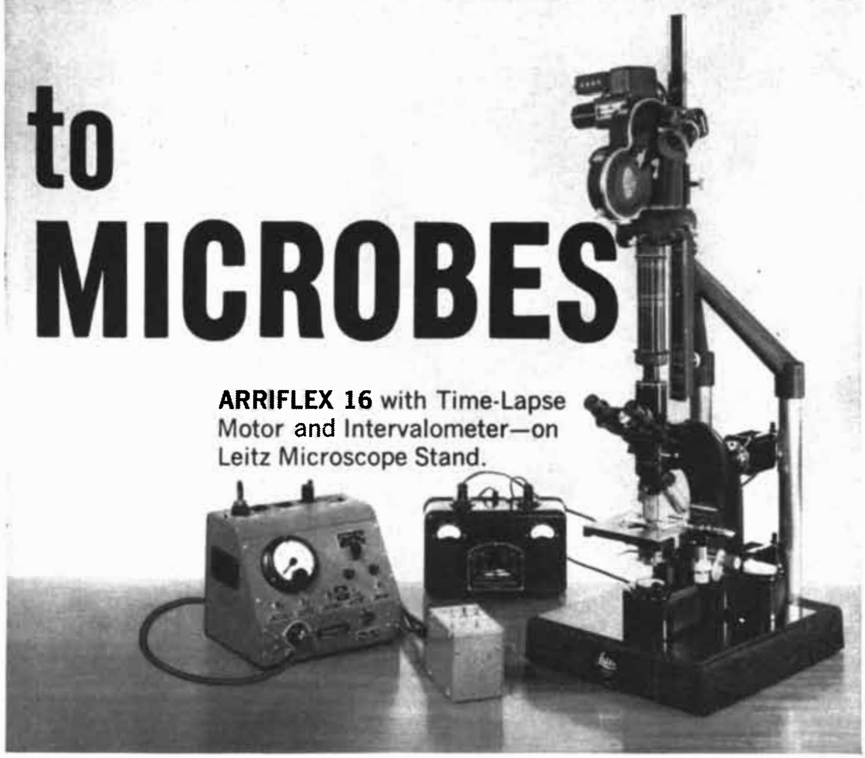

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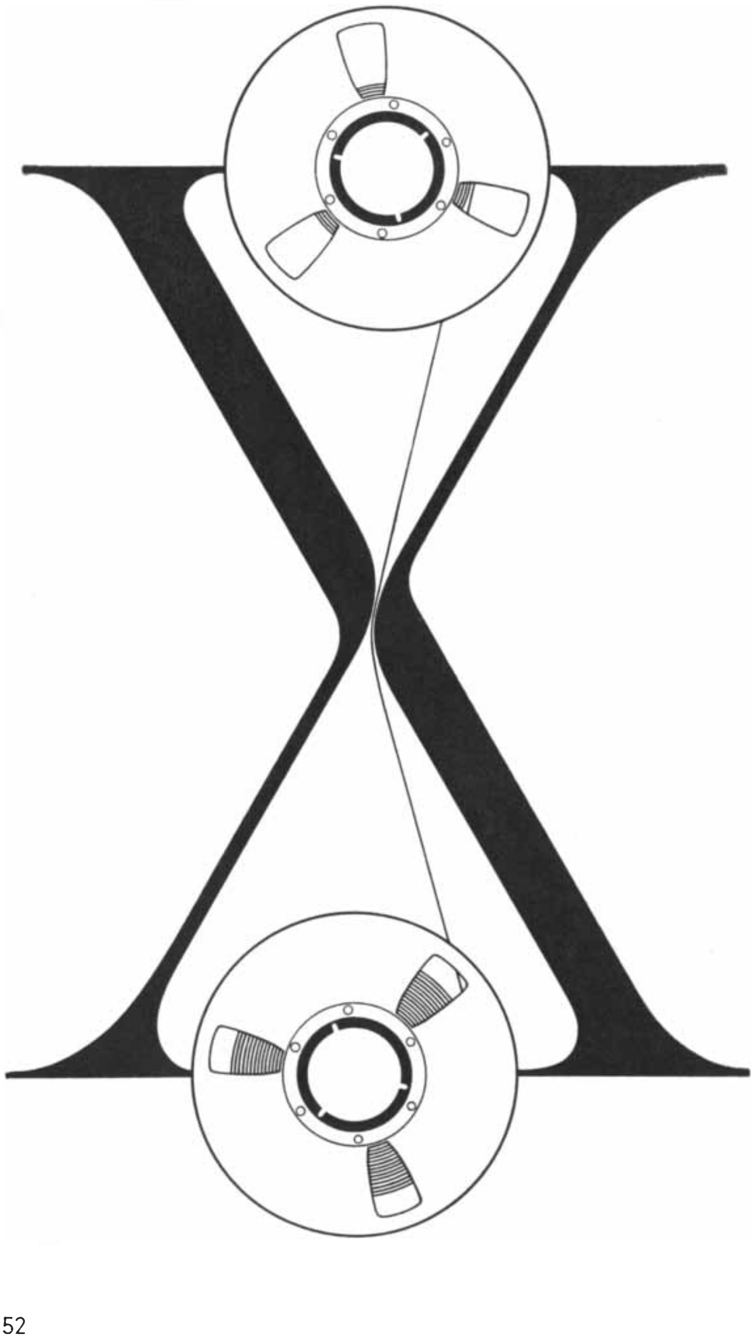
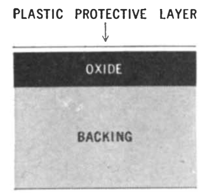


In that narrow little lifeline of data known as magnetic tape, a miss is magnified into a mile. A missed bit, or one picked up by error is confusing, frustrating and time-consuming. If you're in doubt about the kind of performance you're getting, perhaps "Scotch" brand Sandwich Tapes can solve some of your tape and equipment problems.

The exclusive construction of the Sandwich Tapes combats the causes of error because it eliminates the source—oxide rub-off and head build-up. Tests prove it wears a minimum of 10 times as long as ordinary tapes before it errs. As a by-product, you can rely on it to drastically reduce maintenance and replacement costs on equipment.



The Sandwich is constructed as shown in the diagram at the right. The famous "Scotch" brand high potency oxide coating is sandwiched between a tough polyester base and a 50 micro-inch layer of plastic. Since the oxide is never in contact with the head, tape movement is smooth and low in friction—easy on both tape and equipment. Oxide can't rub off and distort valuable data.

Yet, the real meat of this remarkable Sandwich is the "Scotch" brand high potency oxide coating. Even under the protective plastic, the oxide's potency is quite sufficient to pick up 500 pulses per inch—and give desirable high-frequency response in many AM, FM and PDM applications. Sandwich Tape is but one of the developments to come out of 3M research—the same research responsible for "Scotch" brand Video Tape—the first video tape in commercial use.

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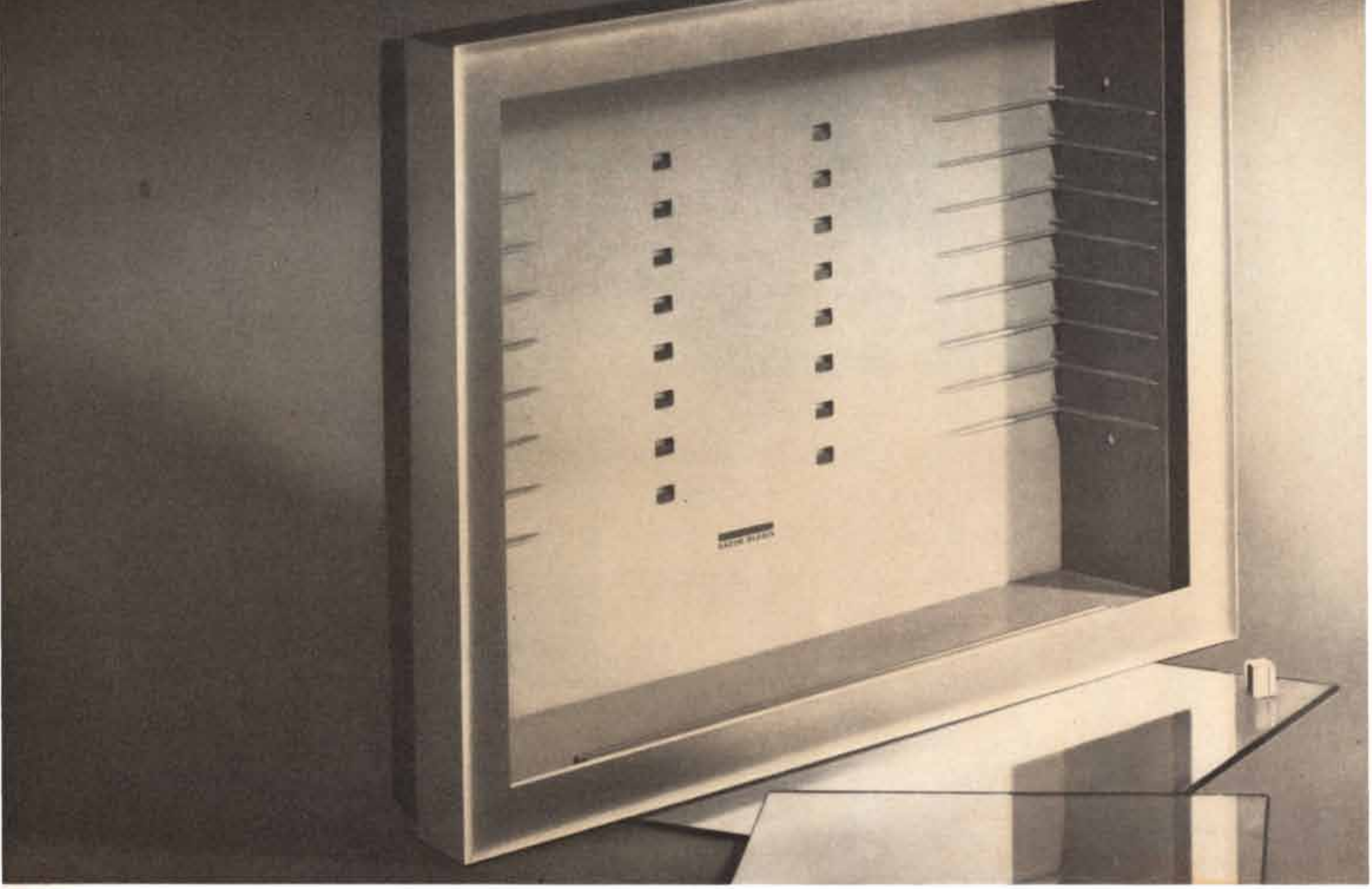

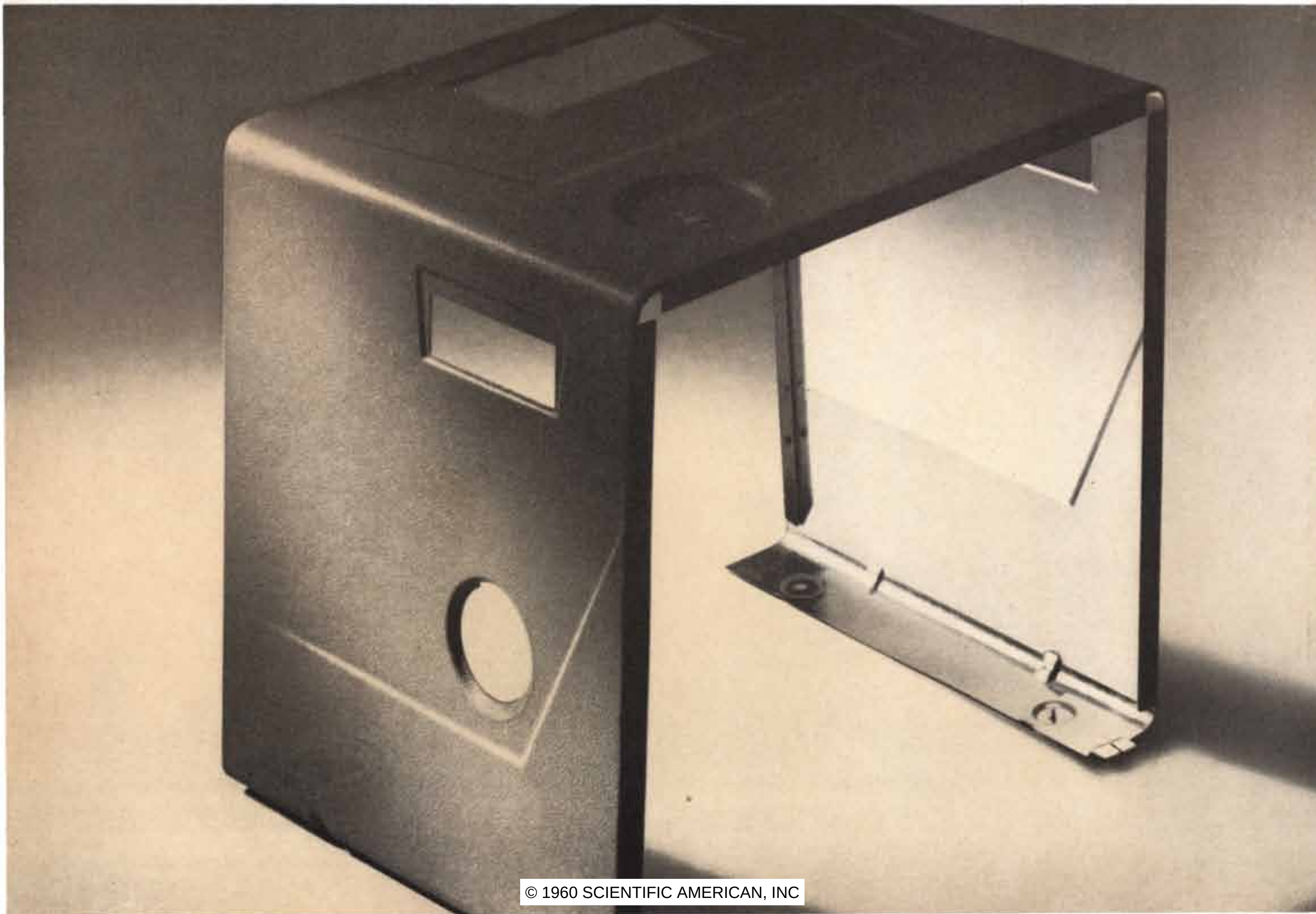

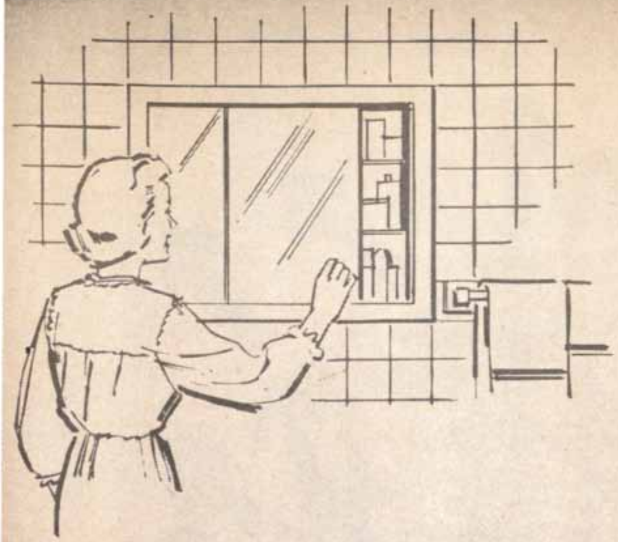

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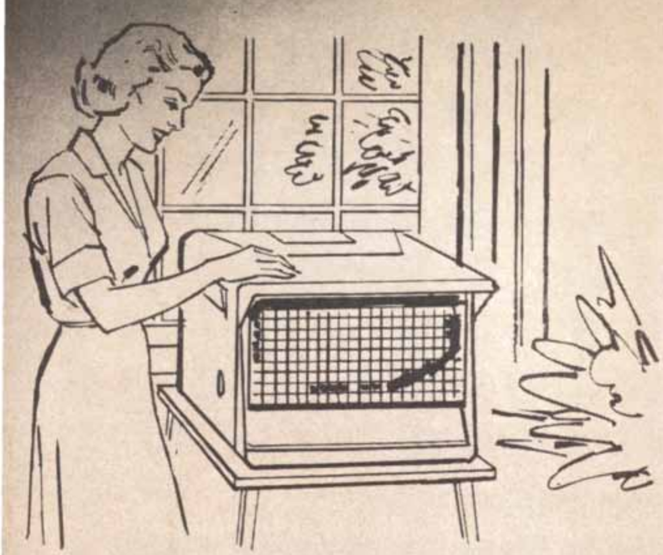

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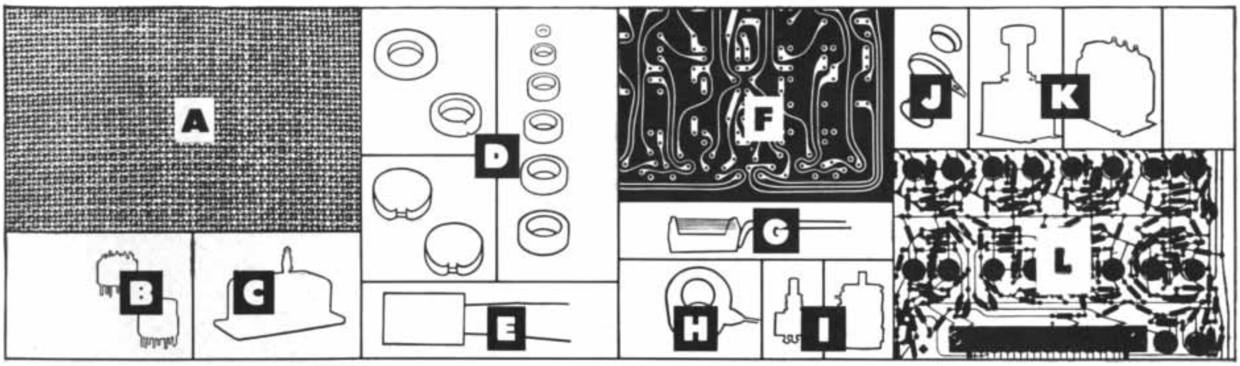

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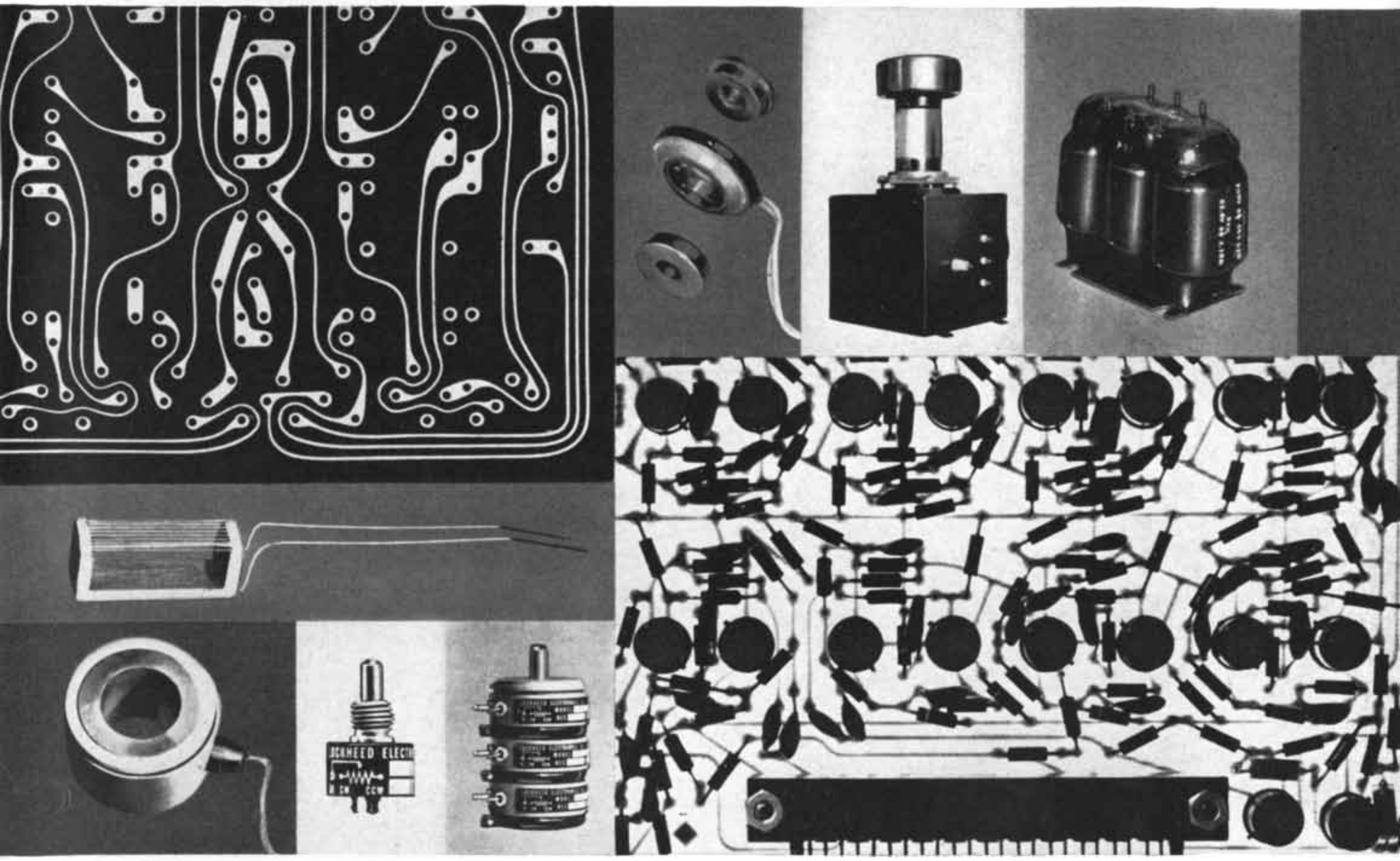

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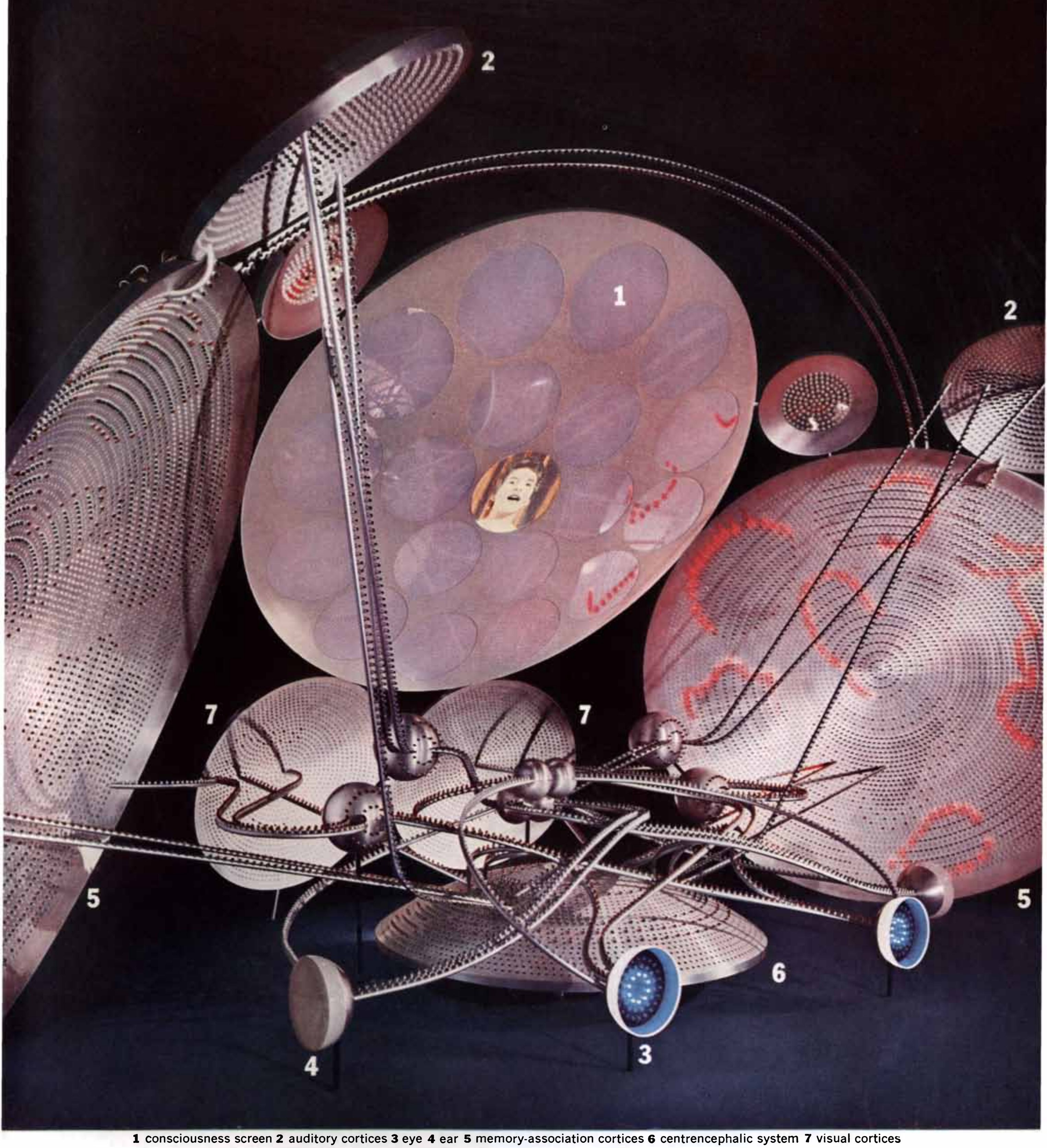

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Tools and Human Evolution

Presenting a series of articles on the human species, with special reference to its origins. It is now clear that tools antedate man, and that their use by prehuman primates gave rise to Homo sapiens

by Sherwood L. Washburn

A series of recent discoveries has linked prehuman primates of half a million years ago with stone tools. For some years investigators had been uncovering tools of the simplest kind from ancient deposits in Africa. At first they assumed that these tools constituted evidence of the existence of large-brained, fully bipedal men. Now the tools have been found in association with much more primitive creatures, the not-fully bipedal, small-brained near-men, or man-apes. Prior to these finds the prevailing view held that man evolved nearly to his present structural state and then discovered tools and the new ways of life that they made possible. Now it appears that man-apes—creatures able to run but not yet walk on two legs, and with brains no larger than those of apes now living—had already learned to make and to use tools. It follows that the structure of modern man must be the result of the change in the terms of natural selection that came with the tool-using way of life.

The earliest stone tools are chips or simple pebbles, usually from river gravels. Many of them have not been shaped at all, and they can be identified as tools only because they appear in concentrations, along with a few worked pieces, in caves or other locations where no such stones naturally occur. The huge advantage that a stone tool gives to its user must be tried to be appreciated. Held in the hand, it can be used for pounding, digging or scraping. Flesh and bone can be cut with a flaked chip, and what would be a mild blow with the fist becomes lethal with a rock in the hand. Stone tools can be employed, moreover, to make tools of other materials. Naturally occurring sticks are nearly all rotten, too large, or of inconvenient shape; some tool for fabrication is essential for the efficient use of wood. The utility of a mere pebble seems so limited to the user of modern tools that it is not easy to comprehend the vast difference that separates the tool-user from the ape which relies on hands and teeth alone. Ground-living monkeys dig out roots for food, and if they could use a stone or a stick, they might easily double their food supply. It was the success of the simplest tools that started the whole trend of human evolution and led to the civilizations of today.

From the short-term point of view, human structure makes human behavior possible. From the evolutionary point of view, behavior and structure form an interacting complex, with each change in one affecting the other. Man began when populations of apes, about a million years ago, started the bipedal, tool-using way of life that gave rise to the man-apes of the genus *Australopithecus*. Most of the obvious differences that distinguish man from ape came after the use of tools.

The primary evidence for the new view of human evolution is teeth, bones and tools. But our ancestors were not fossils; they were striving creatures, full of rage, dominance and the will to live. What evolved was the pattern of life of intelligent, exploratory, playful, vigorous primates; the evolving reality was a succession of social systems based upon the motor abilities, emotions and intelligence of their members. Selection produced new systems of child care, maturation and sex, just as it did alterations in the skull and the teeth. Tools, hunting, fire, complex social life, speech, the human way and the brain evolved together to produce ancient man of the genus *Homo* about half a million years ago. Then the brain evolved under the pressures of more complex social life until the species *Homo sapiens* appeared perhaps as recently as 50,000 years ago.

With the advent of *Homo sapiens* the tempo of technical-social evolution quickened. Some of the early types of tool had lasted for hundreds of thousands of years and were essentially the same throughout vast areas of the African and Eurasian land masses. Now the tool forms multiplied and became regionally diversified. Man invented the

STENCILED HANDS in the cave of Gargas in the Pyrenees date back to the Upper Paleolithic of perhaps 30,000 years ago. Aurignacian man made the images by placing hand against wall and spattering it with paint. Hands stenciled in black (*top*) are more distinct and apparently more recent than those done in other colors (*center*).

OLDUVAI GORGE in Tanganyika is the site where the skull of the largest known man-ape was discovered last summer by L. S. B. Leakey and his wife Mary. Stratigraphic evidence indicates that skull dates back to Lower Pleistocene, more than 500,000 years ago.

bow, boats, clothing; conquered the Arctic; invaded the New World; domesticated plants and animals; discovered metals, writing and civilization. Today, in the midst of the latest tool-making revolution, man has achieved the capacity to adapt his environment to his need and impulse, and his numbers have begun to crowd the planet.

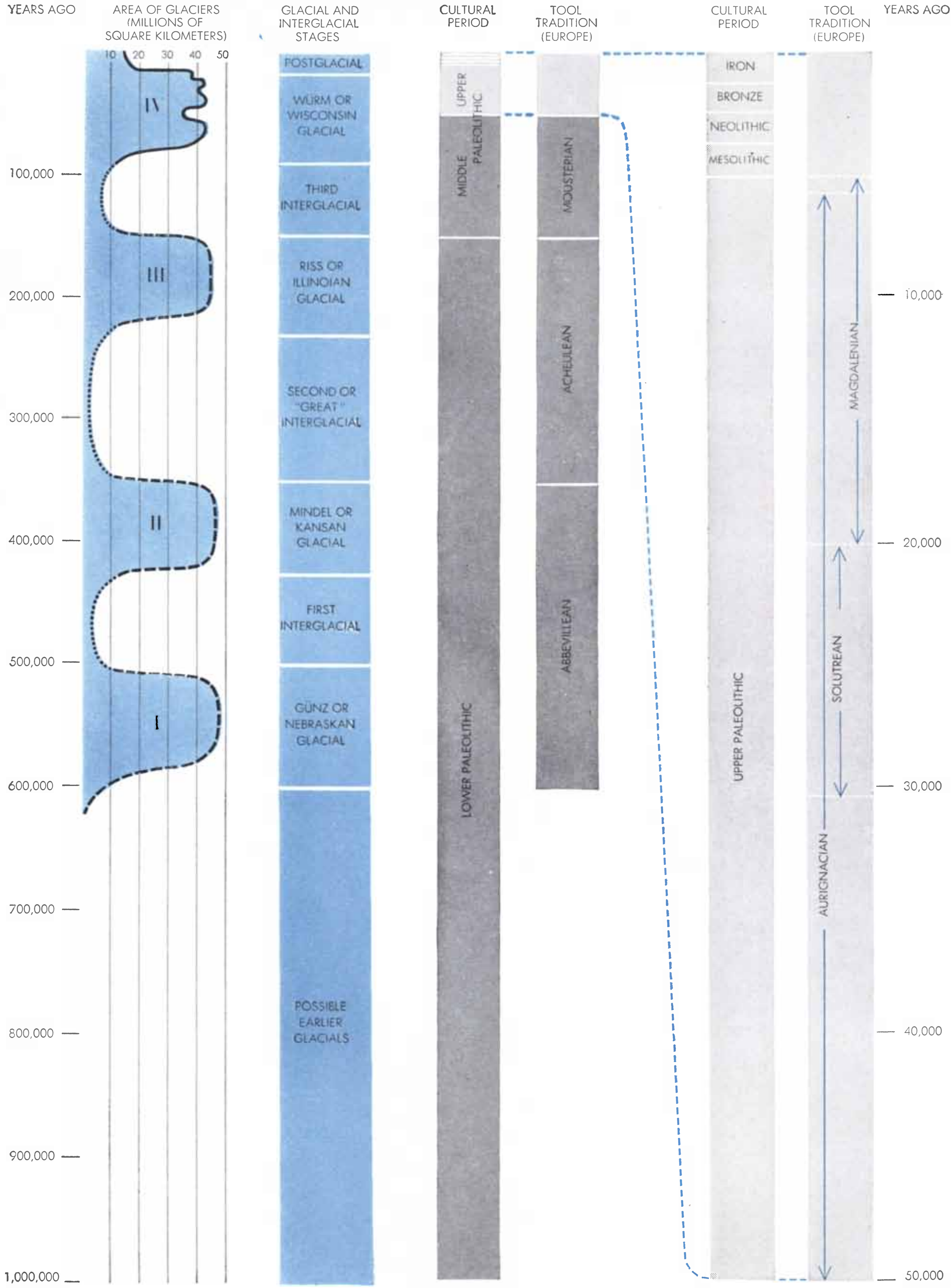
The later events in the evolution of the human species are treated in other articles in this issue of SCIENTIFIC AMERICAN. This article is concerned with the beginnings of the process by which, as Theodosius Dobzhansky says in the concluding article of the issue, biological evolution has transcended itself. From the rapidly accumulating evidence it is now possible to speculate with some confidence on the manner in which the way of life made possible by tools changed the pressures of natural selection and so changed the structure of man.

Tools have been found, along with the bones of their makers, at Sterkfontein, Swartkrans and Kromdraai in South Africa and at Olduvai in Tanganyika. Many of the tools from Sterkfontein are merely unworked river pebbles, but someone had to carry them from the gravels some miles away and bring them to the deposit in which they are found. Nothing like them occurs naturally in the local limestone caves. Of course the association of the stone tools with man-ape bones in one or two localities does not prove that these animals made the tools. It has been argued that a more advanced form of man, already present, was the toolmaker. This argument has a familiar ring to students of human evolution. Peking man was thought too primitive to be a toolmaker; when the first manlike pelvis was found with man-ape bones, some argued that it must have fallen into the deposit because it was too human to be associated with the skull. In every case, however, the repeated discovery of the same unanticipated association has ultimately settled the controversy.

This is why the discovery by L. S. B. and Mary Leakey in the summer of 1959 is so important. In Olduvai Gorge in Tanganyika they came upon traces of an old living site, and found stone tools in clear association with the largest man-ape skull known. With the stone tools were a hammer stone and waste flakes from the manufacture of the tools. The deposit also contained the bones of rats, mice, frogs and some bones of juvenile pig and antelope, showing that even the largest and latest of the

SKULL IS EXAMINED ***in situ*** **by Mary Leakey, who first noticed fragments of it protruding from the cliff face at left. Pebble tools were found at the same level as the skull.**

SKULL IS EXCAVATED from surrounding rock with dental picks. Although skull was badly fragmented, almost all of it was recovered. Fragment visible here is part of upper jaw.



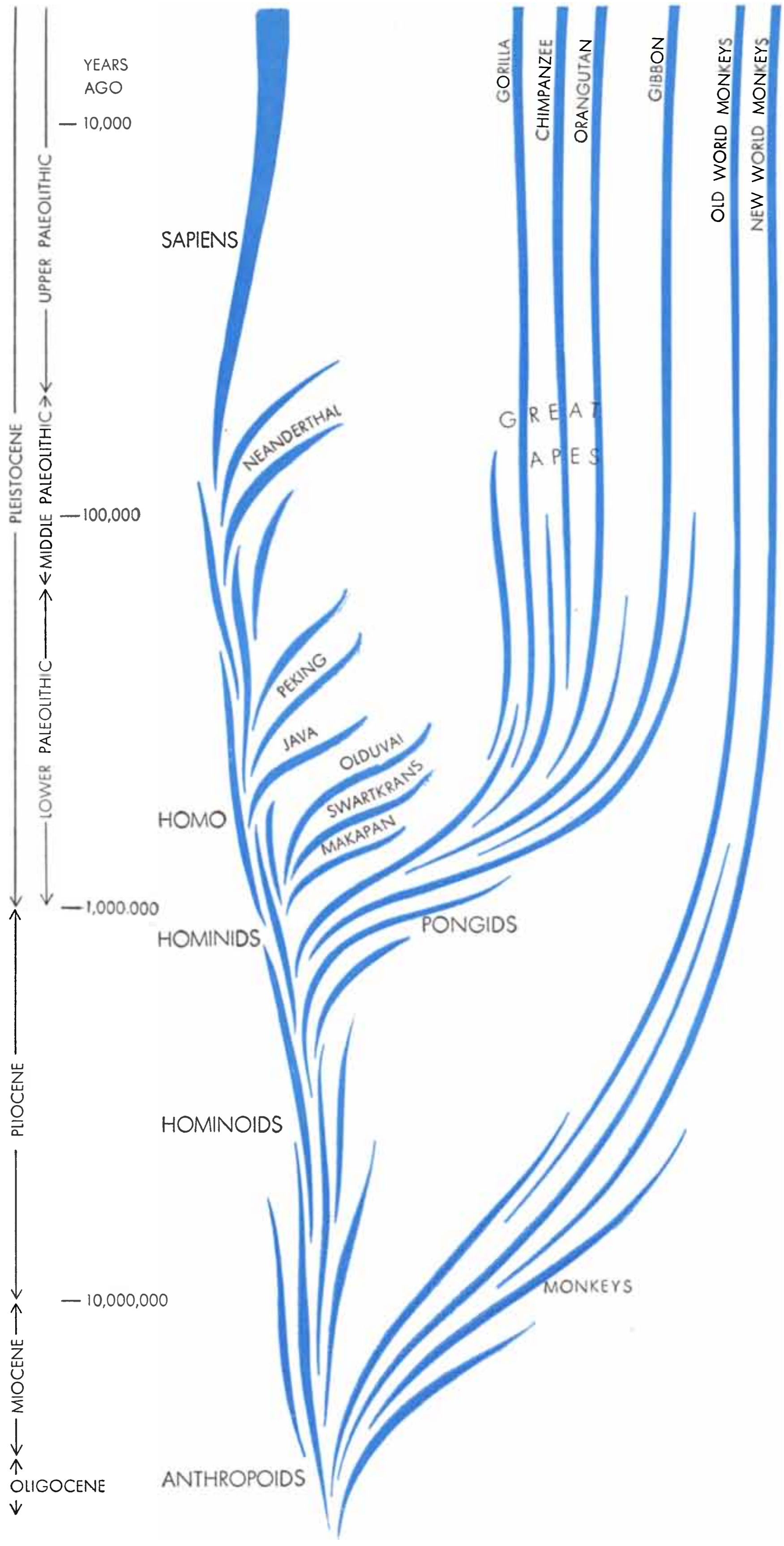
TIME-SCALE correlates cultural periods and tool traditions with the four great glaciations of the Pleistocene epoch. Glacial advances and retreats shown by solid black curve are accurately known; those shown by broken curve are less certain; those shown by dotted curve are uncertain. Light gray bars at far right show an expanded view of last 50,000 years on two darker bars at center. Scale was prepared with the assistance of William R. Farrand of the Lamont Geological Observatory of Columbia University.

man-apes could kill only the smallest animals and must have been largely vegetarian. The Leakeys' discovery confirms the association of the man-ape with pebble tools, and adds the evidence of manufacture to that of mere association. Moreover, the stratigraphic evidence at Olduvai now for the first time securely dates the man-apes, placing them in the lower Pleistocene, earlier than 500,000 years ago and earlier than the first skeletal and cultural evidence for the existence of the genus Homo [*see illustration on next two pages*]. Before the discovery at Olduvai these points had been in doubt.

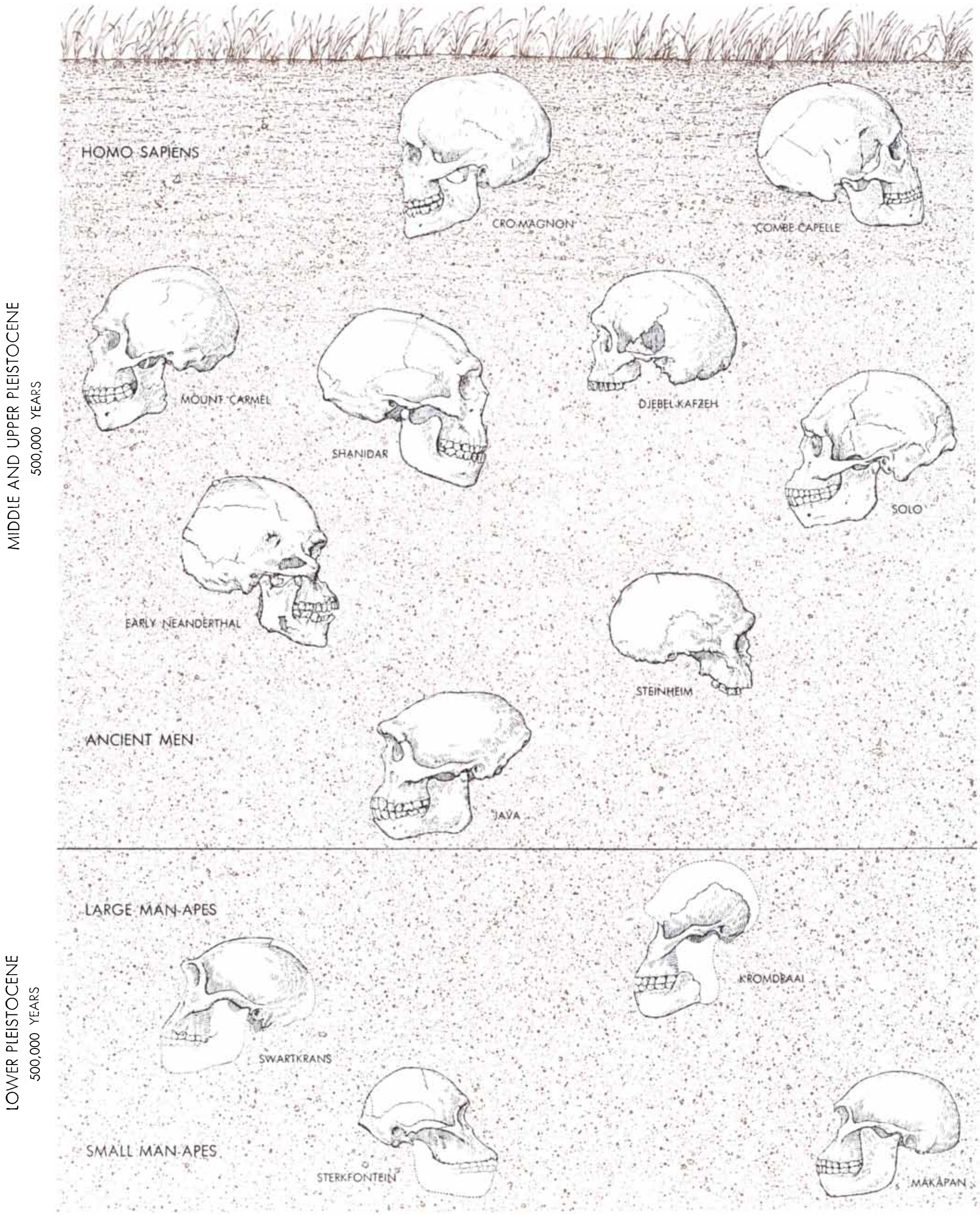
The man-apes themselves are known from several skulls and a large number of teeth and jaws, but only fragments of the rest of the skeleton have been preserved. There were two kinds of man-ape, a small early one that may have weighed 50 or 60 pounds and a later and larger one that weighed at least twice as much. The differences in size and form between the two types are quite comparable to the differences between the contemporary pygmy chimpanzee and the common chimpanzee.

Pelvic remains from both forms of man-ape show that these animals were bipedal. From a comparison of the pelvis of ape, man-ape and man it can be seen that the upper part of the pelvis is much wider and shorter in man than in the ape, and that the pelvis of the man-ape corresponds closely, though not precisely, to that of modern man [*see top illustration on page 71*]. The long upper pelvis of the ape is characteristic of most mammals, and it is the highly specialized, short, wide bone in man that makes possible the human kind of bipedal locomotion. Although the man-ape pelvis is apelike in its lower part, it approaches that of man in just those features that distinguish man from all other animals. More work must be done before this combination of features is fully understood. My belief is that bipedal running, made possible by the changes in the upper pelvis, came before efficient bipedal walking, made possible by the changes in the lower pelvis. In the man-ape, therefore, the adaptation to bipedal locomotion is not yet complete. Here, then, is a phase of human evolution characterized by forms that are mostly bipedal, small-brained, plains-living, tool-making hunters of small animals.

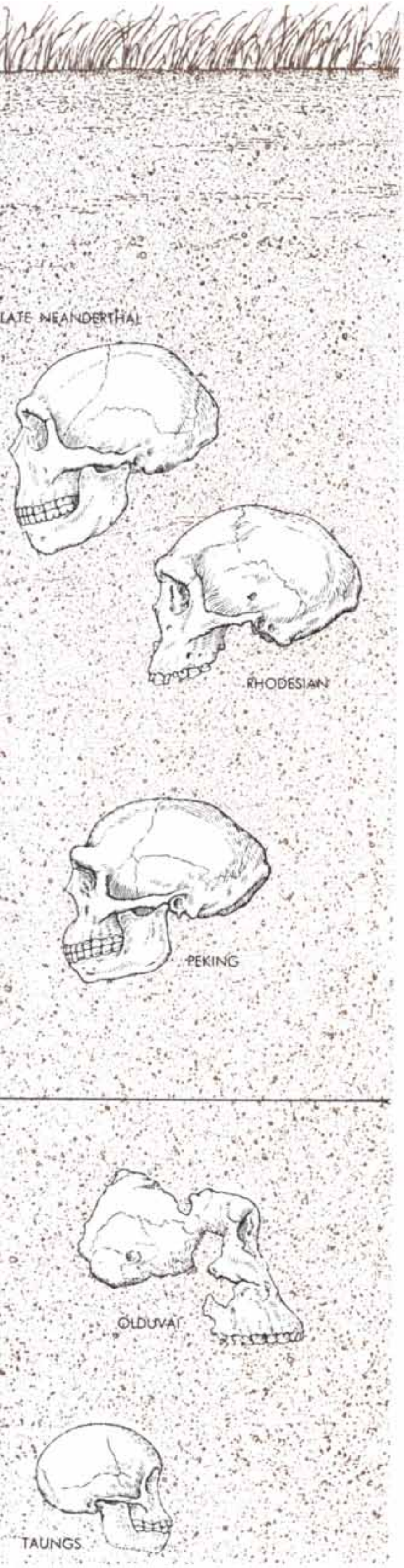
The capacity for bipedal walking is primarily an adaptation for covering long distances. Even the arboreal chimpanzee can run faster than a man, and any monkey can easily outdistance him.



LINES OF DESCENT that lead to man and his closer living relatives are charted. The hominoid superfamily diverged from the anthropoid line in the Miocene period some 20 million years ago. From the hominoid line came the tool-using hominids at the beginning of the Pleistocene. The genus *Homo* appeared in the hominid line during the first interglacial (*see chart on opposite page*); the species *Homo sapiens*, around 50,000 years ago.



FOSSIL SKULLS of Pleistocene epoch reflect transition from man-apes (*below black line*) to *Homo sapiens* (*top*). Relative age of intermediate specimens is indicated schematically by their position on page. Java man (*middle left*) and Solo man (*upper center*) are members of the genus *Pithecanthropus*, and are related to Peking man (*middle right*). The Shanidar skull (*upper left*) be-



longs to the Neanderthal family, while Mount Carmel skull shows characteristics of Neanderthal and modern man.

A man, on the other hand, can walk for many miles, and this is essential for efficient hunting. According to skeletal evidence, fully developed walkers first appeared in the ancient men who inhabited the Old World from 500,000 years ago to the middle of the last glaciation. These men were competent hunters, as is shown by the bones of the large animals they killed. But they also used fire and made complicated tools according to clearly defined traditions. Along with the change in the structure of the pelvis, the brain had doubled in size since the time of the man-apes.

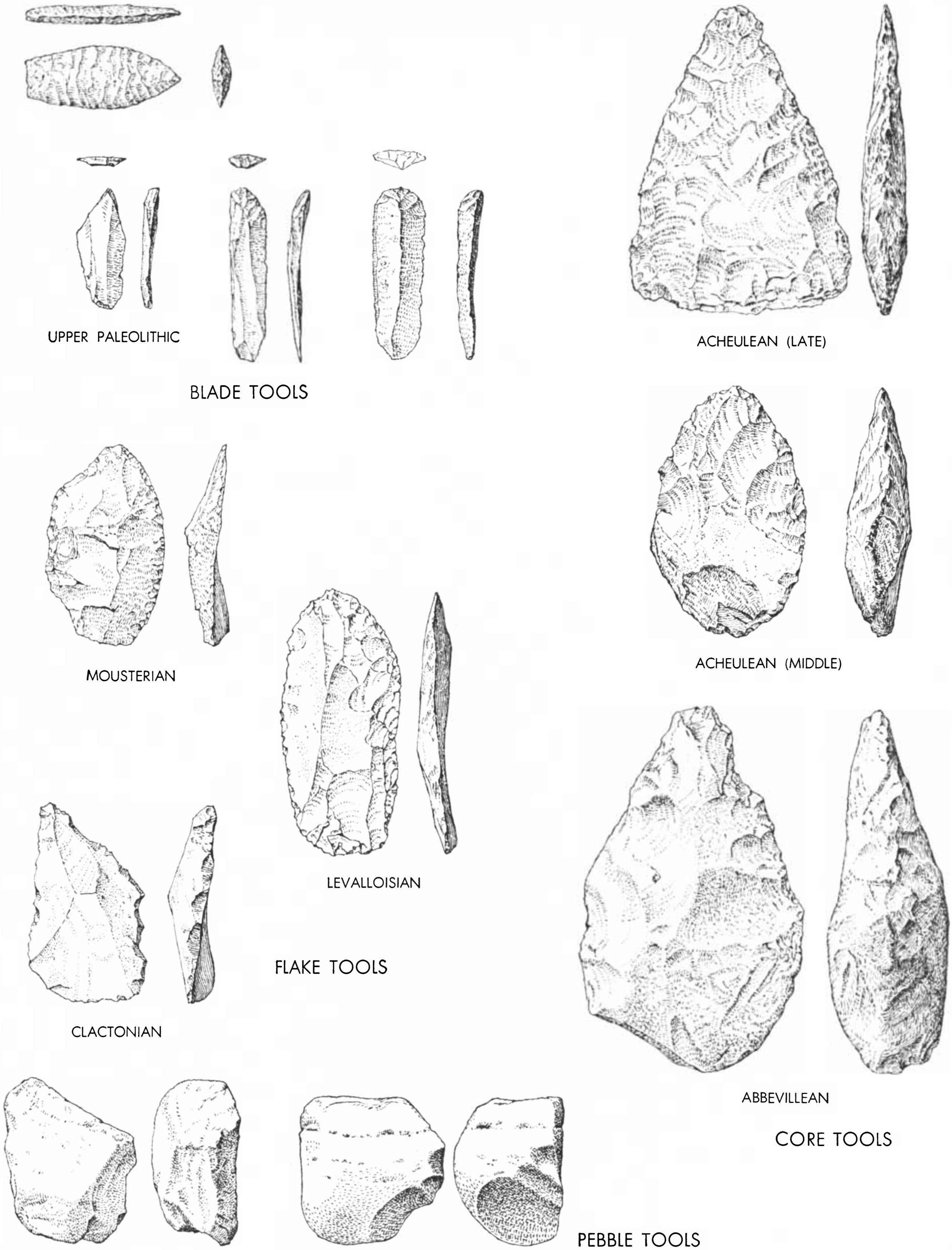
The fossil record thus substantiates the suggestion, first made by Charles Darwin, that tool use is both the cause and the effect of bipedal locomotion. Some very limited bipedalism left the hands sufficiently free from locomotor functions so that stones or sticks could be carried, played with and used. The advantage that these objects gave to their users led both to more bipedalism and to more efficient tool use. English lacks any neat expression for this sort of situation, forcing us to speak of cause and effect as if they were separated, whereas in natural selection cause and effect are interrelated. Selection is based on successful behavior, and in the man-apes the beginnings of the human way of life depended on both inherited locomotor capacity and on the learned skills of tool-using. The success of the new way of life based on the use of tools changed the selection pressures on many parts of the body, notably the teeth, hands and brain, as well as on the pelvis. But it must be remembered that selection was for the whole way of life.

In all the apes and monkeys the males have large canine teeth. The long upper canine cuts against the first lower premolar, and the lower canine passes in front of the upper canine. This is an efficient fighting mechanism, backed by very large jaw muscles. I have seen male baboons drive off cheetahs and dogs, and according to reliable reports male baboons have even put leopards to flight. The females have small canines, and they hurry away with the young under the very conditions in which the males turn to fight. All the evidence from living monkeys and apes suggests that the male's large canines are of the greatest importance to the survival of the group, and that they are particularly important in ground-living forms that may not be able to climb to safety in the trees. The small, early man-apes lived in open plains country, and yet none of them had large canine teeth. It would appear that the protection of the group must have shifted from teeth to tools early in the evolution of the man-apes, and long before the appearance of the forms that have been found in association with stone tools. The tools of Sterkfontein and Olduvai represent not the beginnings of tool use, but a choice of material and knowledge in manufacture which, as is shown by the small canines of the man-apes that deposited them there, derived from a long history of tool use.

Reduction in the canine teeth is not a simple matter, but involves changes in the muscles, face, jaws and other parts of the skull. Selection builds powerful neck muscles in animals that fight with their canines, and adapts the skull to the action of these muscles. Fighting is not a matter of teeth alone, but also of seizing, shaking and hurling an enemy's body with the jaws, head and neck. Reduction in the canines is therefore accompanied by a shortening in the jaws, reduction in the ridges of bone over the eyes and a decrease in the shelf of bone in the neck area [*see illustration on page 72*]. The reason that the skulls of the females and young of the apes look more like man-apes than those of adult males is that, along with small canines, they have smaller muscles and all the numerous structural features that go along with them. The skull of the man-ape is that of an ape that has lost the structure for effective fighting with its teeth. Moreover, the man-ape has transferred to its hands the functions of seizing and pulling, and this has been attended by reduction of its incisors. Small canines and incisors are biological symbols of a changed way of life; their primitive functions are replaced by hand and tool.

The history of the grinding teeth—the molars—is different from that of the seizing and fighting teeth. Large size in any anatomical structure must be maintained by positive selection; the selection pressure changed first on the canine teeth and, much later, on the molars. In the man-apes the molars were very large, larger than in either ape or man. They were heavily worn, possibly because food dug from the ground with the aid of tools was very abrasive. With the men of the Middle Pleistocene, molars of human size appear along with complicated tools, hunting and fire.

The disappearance of brow ridges and the refinement of the human face may involve still another factor. One of the essential conditions for the organi-

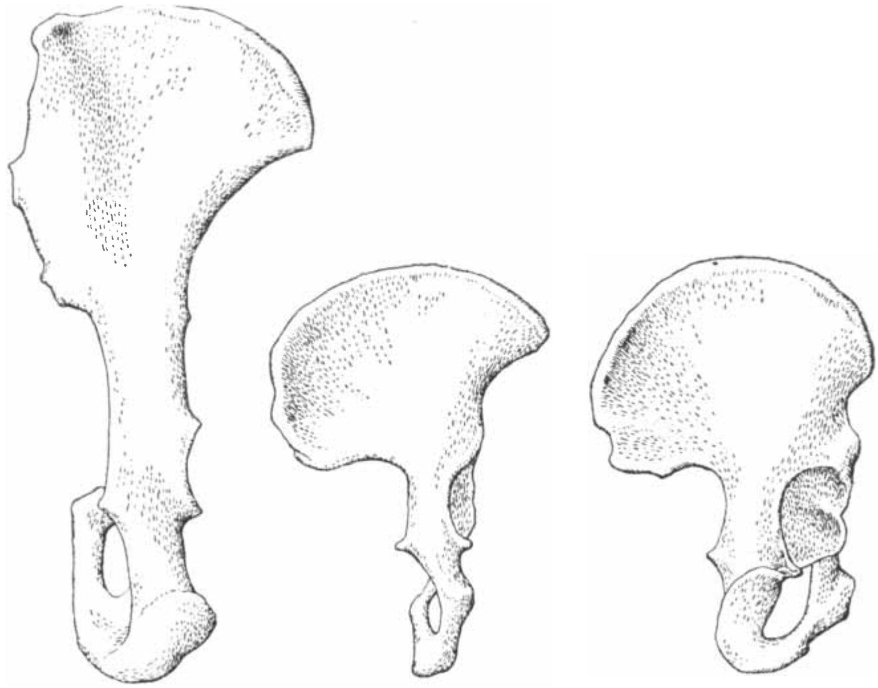


TOOL TRADITIONS of Europe are the main basis for classifying Paleolithic cultures. The earliest tools are shown at bottom of page; later ones, at top. The tools are shown from both the side and the edge, except for blade tools, which are shown in three views. Tools consisting of a piece of stone from which a few flakes have been chipped are called core tools (*right*). Other types of tool were made from flakes (*center and left*); blade tools were made from flakes with almost parallel sides. Tool traditions are named for site where tools of a given type were discovered; Acheulean tools, for example, are named for St. Acheul in France.

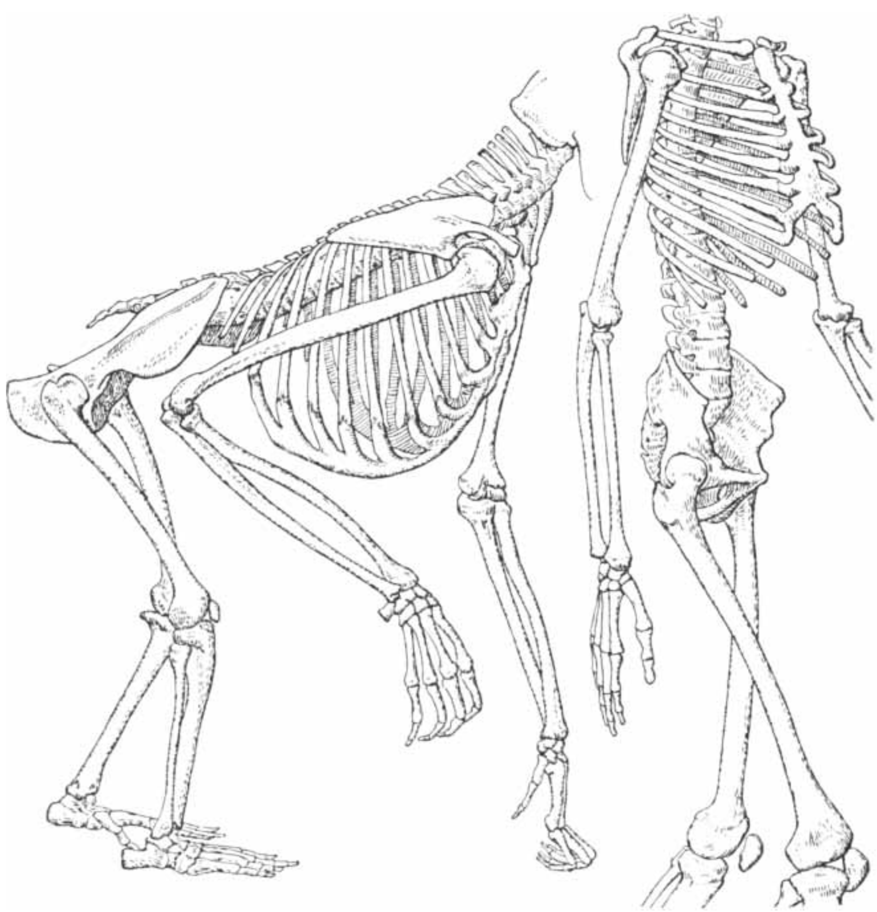
zation of men in co-operative societies was the suppression of rage and of the uncontrolled drive to first place in the hierarchy of dominance. Recently it has been shown that domestic animals, chosen over the generations for willingness to adjust and for lack of rage, have relatively small adrenal glands, as Curt P. Richter of Johns Hopkins University has shown. But the breeders who selected for this hormonal, physiological, temperamental type also picked, without realizing it, animals with small brow ridges and small faces. The skull structure of the wild rat bears the same relation to that of the tame rat as does the skull of Neanderthal man to that of *Homo sapiens*. The same is true for the cat, dog, pig, horse and cow; in each case the wild form has the larger face and muscular ridges. In the later stages of human evolution, it appears, the self-domestication of man has been exerting the same effects upon temperament, glands and skull that are seen in the domestic animals.

Of course from man-ape to man the brain-containing part of the skull has also increased greatly in size. This change is directly due to the increase in the size of the brain: as the brain grows, so grow the bones that cover it. Since there is this close correlation between brain size and bony brain-case, the brain size of the fossils can be estimated. On the scale of brain size the man-apes are scarcely distinguishable from the living apes, although their brains may have been larger with respect to body size. The brain seems to have evolved rapidly, doubling in size between man-ape and man. It then appears to have increased much more slowly; there is no substantial change in gross size during the last 100,000 years. One must remember, however, that size alone is a very crude indicator, and that brains of equal size may vary greatly in function. My belief is that although the brain of *Homo sapiens* is no larger than that of Neanderthal man, the indirect evidence strongly suggests that the first *Homo sapiens* was a much more intelligent creature.

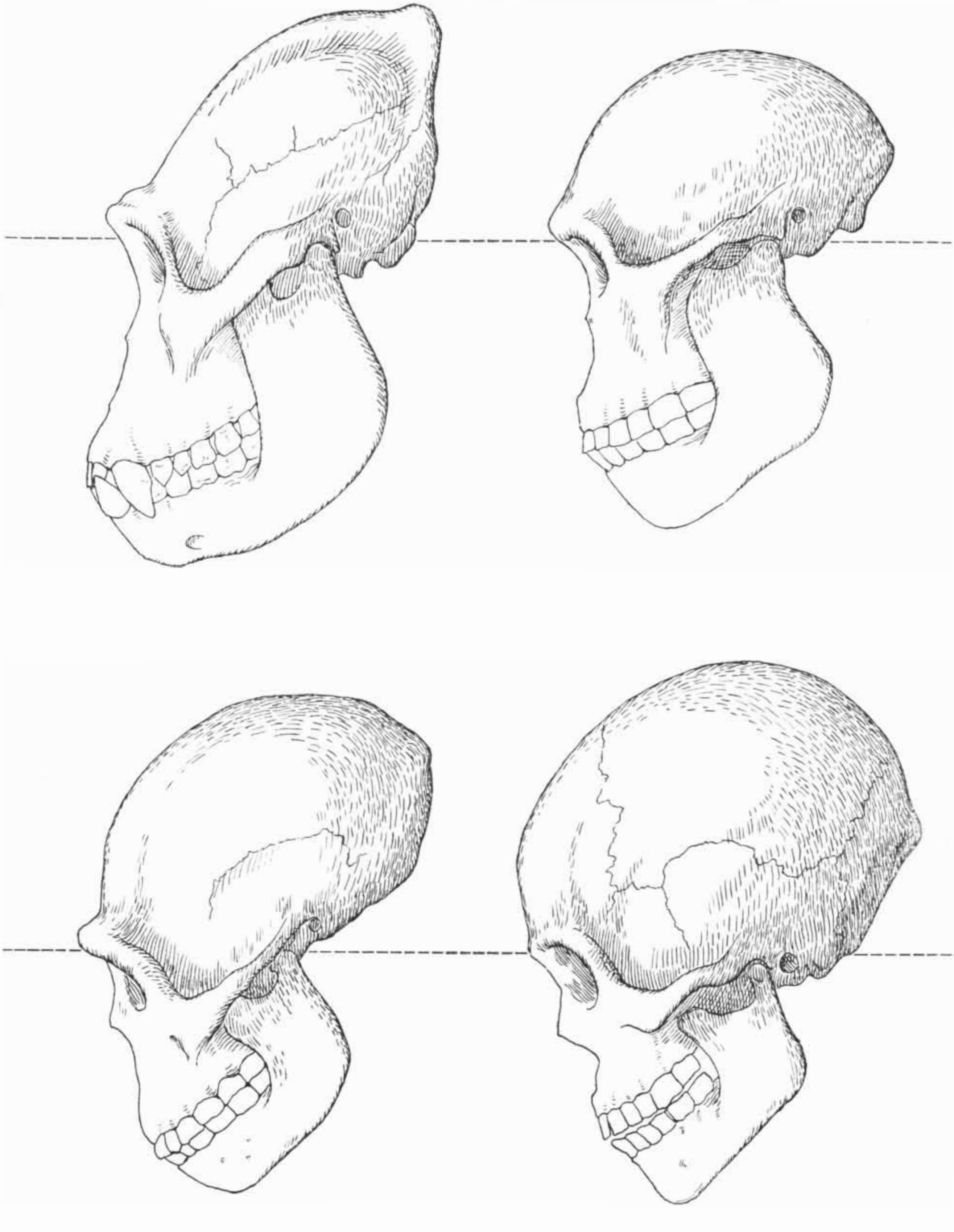
The great increase in brain size is important because many functions of the brain seem to depend on the number of cells, and the number increases with volume. But certain parts of the brain have increased in size much more than others. As functional maps of the cortex of the brain show, the human sensory-motor cortex is not just an enlargement of that of an ape [*see illustrations on last three pages of this article*]. The areas



HIP BONES of ape (*left*), man-ape (*center*) and man (*right*) reflect differences between quadruped and biped. Upper part of human pelvis is wider and shorter than that of apes. Lower part of man-ape pelvis resembles that of ape; upper part resembles that of man.



POSTURE of gorilla (*left*) and man (*right*) is related to size, shape and orientation of pelvis. Long, straight pelvis of ape provides support for quadrupedal locomotion; short, broad pelvis of man curves backward, carrying spine and torso in bipedal position.



EVOLUTION OF SKULL from ape (*upper left*) to man-ape (*upper right*) to ancient man (*lower left*) to modern man (*lower right*) involves an increase in size of brain case (*part of skull above broken lines*) and a corresponding decrease in size of face (*part of skull below broken lines*). Apes also possess canine teeth that are much larger than those found in either man-apes or man.

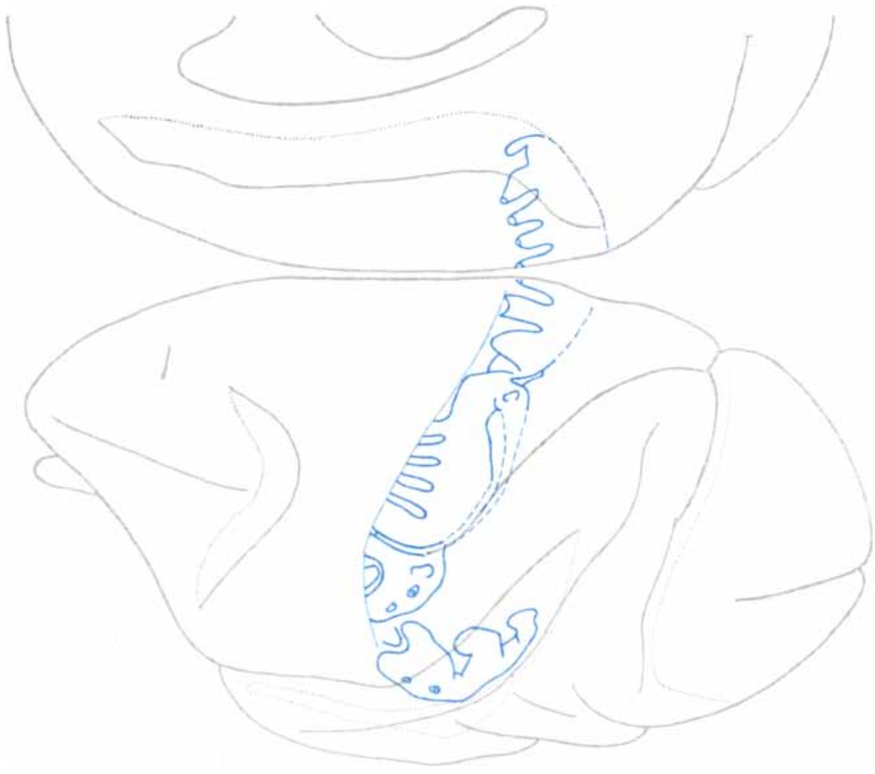
for the hand, especially the thumb, in man are tremendously enlarged, and this is an integral part of the structural base that makes the skillful use of the hand possible. The selection pressures that favored a large thumb also favored a large cortical area to receive sensations from the thumb and to control its motor activity. Evolution favored the development of a sensitive, powerful, skillful thumb, and in all these ways —as well as in structure—a human thumb differs from that of an ape.

The same is true for other cortical areas. Much of the cortex in a monkey is still engaged in the motor and sensory functions. In man it is the areas adjacent to the primary centers that are most expanded. These areas are concerned with skills, memory, foresight and language; that is, with the mental faculties that make human social life possible. This is easiest to illustrate in the field of language. Many apes and monkeys can make a wide variety of sounds. These sounds do not, however, develop into language [see "The Origin of Speech," by Charles F. Hockett, page 88]. Some workers have devoted great efforts, with minimum results, to trying to teach chimpanzees to talk. The reason is that there is little in the brain to teach. A human child learns to speak with the greatest ease, but the storage of thousands of words takes a great deal of cortex. Even the simplest language must have given great advantage to those first men who had it. One is tempted to think that language may have appeared together with the fine tools, fire and complex hunting of the large-brained men of the Middle Pleistocene, but there is no direct proof of this.

The main point is that the kind of animal that can learn to adjust to complex, human, technical society is a very different creature from a tree-living ape, and the differences between the two are rooted in the evolutionary process. The reason that the human brain makes the human way of life possible is that it is the result of that way of life. Great masses of the tissue in the human brain are devoted to memory, planning, language and skills, because these are the abilities favored by the human way of life.

The emergence of man's large brain occasioned a profound change in the plan of human reproduction. The human mother-child relationship is unique among the primates as is the use of tools. In all the apes and monkeys the baby clings to the mother; to be able to do so,

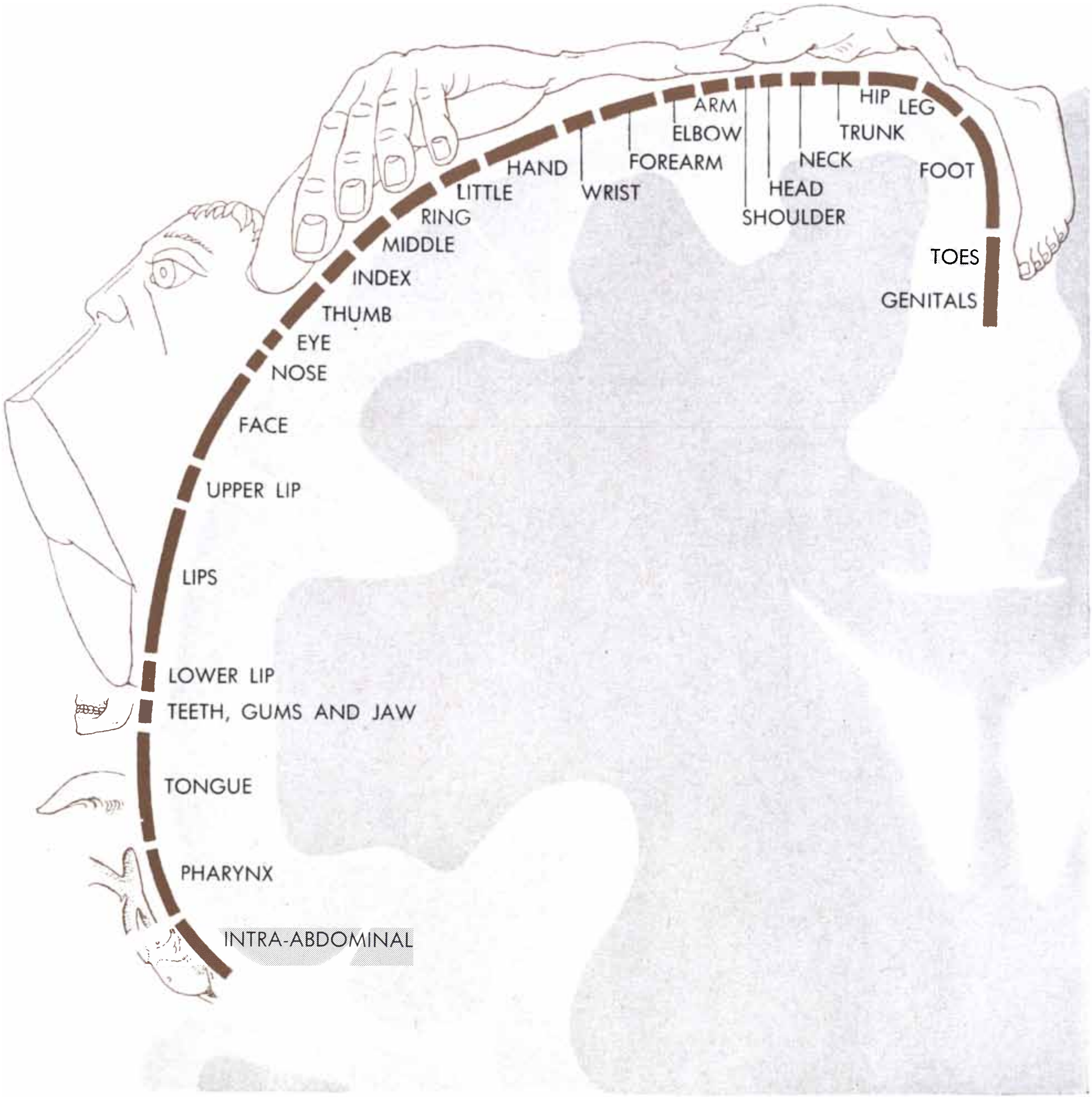
MOTOR CORTEX OF MONKEY controls the movements of the body parts outlined by the superimposed drawing of the animal (*color*). Gray lines trace the surface features of the left half of the brain (*bottom*) and part of the right half (*top*). Colored drawing is distorted in proportion to amount of cortex associated with functions of various parts of the body. Smaller animal in right half of brain indicates location of secondary motor cortex.



SENSORY CORTEX OF MONKEY is mapped in same way as motor cortex (*above*). As in motor cortex, a large area is associated with hands and feet. Smaller animal at bottom of left half of brain indicates location of secondary sensory cortex. Drawings are based on work of Clinton N. Woolsey and his colleagues at the University of Wisconsin Medical School.

the baby must be born with its central nervous system in an advanced state of development. But the brain of the fetus must be small enough so that birth may take place. In man adaptation to bipedal locomotion decreased the size of the bony birth-canal at the same time that the exigencies of tool use selected for larger brains. This obstetrical dilemma was solved by delivery of the fetus at a much earlier stage of development. But this was possible only because the mother, already bipedal and with hands free of locomotor necessities, could hold the helpless, immature infant. The small-brained man-ape probably developed in the uterus as much as the ape does; the human type of mother-child relation must have evolved by the time of the large-brained, fully bipedal humans of the Middle Pleistocene. Bipedalism, tool use and selection for large brains thus slowed human development and invoked far greater maternal responsibility. The slow-moving mother, carrying the baby, could not hunt, and the combination of the woman's obligation to care for slow-developing babies and the man's occupation of hunting imposed a fundamental pattern on the social organization of the human species.

As Marshall D. Sahlins suggests in this issue [see "The Origin of Society," page 76], human society was heavily conditioned at the outset by still other significant aspects of man's sexual adaptation. In the monkeys and apes year-round sexual activity supplies the social bond that unites the primate horde. But sex in these species is still subject to physiological—especially glandular—controls. In man these controls are gone, and are replaced by a bewildering variety of social customs. In no other primate does

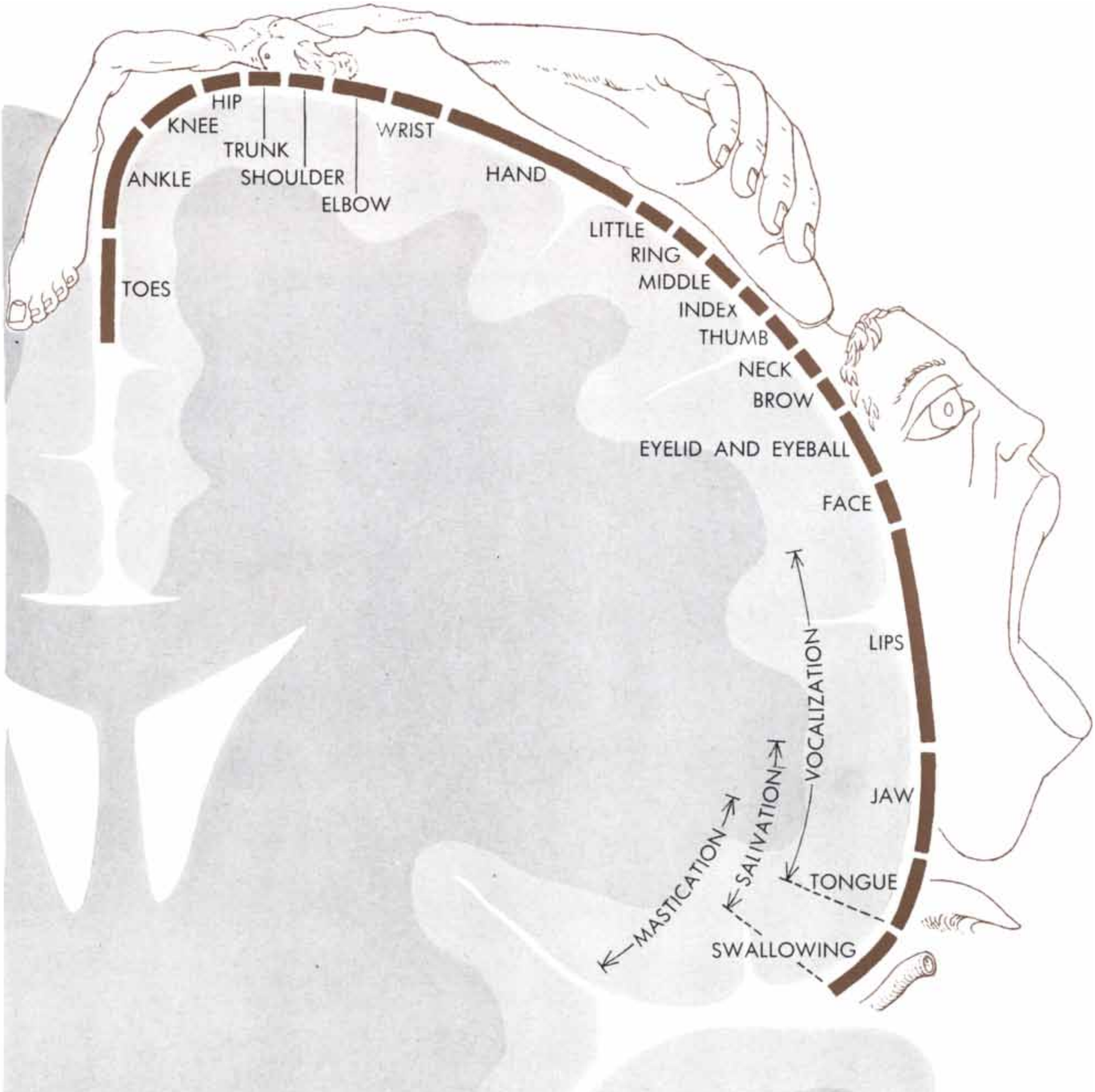


SENSORY HOMUNCULUS is a functional map of the sensory cortex of the human brain worked out by Wilder Penfield and his associates at the Montreal Neurological Institute. As in the map of the sensory cortex of the monkey that appears on the preceding page, the distorted anatomical drawing (*color*) indicates the areas of the sensory cortex associated with the various parts of the body.

a family exist that controls sexual activity by custom, that takes care of slow-growing young, and in which—as in the case of primitive human societies—the male and female provide different foods for the family members.

All these family functions are ultimately related to tools, hunting and the enlargement of the brain. Complex and technical society evolved from the sporadic tool-using of an ape, through the simple pebble tools of the man-ape and the complex toolmaking traditions of ancient men to the hugely complicated culture of modern man. Each behavioral stage was both cause and effect of biological change in bones and brain. These concomitant changes can be seen in the scanty fossil record and can be inferred from the study of the living forms.

Surely as more fossils are found these ideas will be tested. New techniques of investigation, from planned experiments in the behavior of lower primates to more refined methods of dating, will extract wholly new information from the past. It is my belief that, as these events come to pass, tool use will be found to have been a major factor, beginning with the initial differentiation of man and ape. In ourselves we see a structure, physiology and behavior that is the result of the fact that some populations of apes started to use tools a million years ago. The pebble tools constituted man's principal technical adaptation for a period at least 50 times as long as recorded history. As we contemplate man's present eminence, it is well to remember that, from the point of view of evolution, the events of the last 50,000 years occupy but a moment in time. Ancient man endured at least 10 times as long and the man-apes for an even longer time.



MOTOR HOMUNCULUS depicts parts of body and areas of motor cortex that control their functions. Human brain is shown here in coronal (ear-to-ear) cross section. Speech and hand areas of both motor and sensory cortex in man are proportionately much larger than corresponding areas in apes and monkeys, as can be seen by comparing homunculi with diagram of monkey cortex.

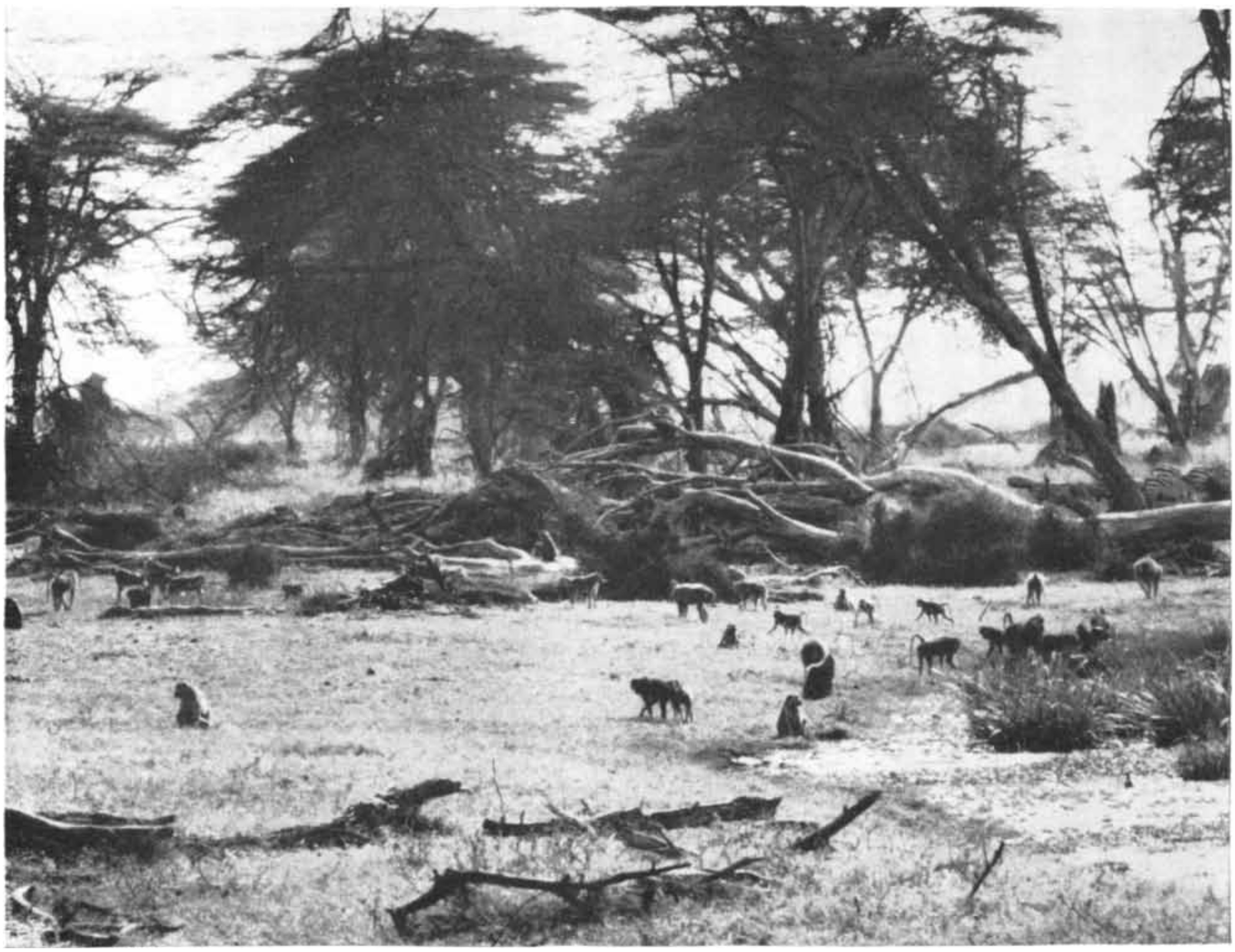
The Origin of Society

As prehuman primates evolved into men, how did the primate horde evolve into the human band? One of the key changes seems to have been the subordination of sexual drives to the needs of the group

by Marshall D. Sahlins

This discussion of the early phases of human society considers events that occurred a million years ago, in places not specifically determined, under circumstances known only by informed speculation. It will therefore be an exercise in inference, not in observation. This means juxtaposing the social life of man's closest relations—monkeys and apes—on the one side, with the organization of known primitive societies on the other. The gap that remains is then bridged by the mind.

No living primate can be directly equated with man's actual simian ancestor, and no contemporary primitive people is identical with our cultural ancestors. In both instances only generalized social traits—not particular, specialized ones—can be selected for historical comparison. On the primate side one must rely primarily on the few field reports of free-ranging groups and on certain pioneer studies of captive animals. These



TROOP OF BABOONS, photographed in Africa by Sherwood L. Washburn and his son Stanley, is an example of the primate horde. Depending on the species, the primate horde varies in size from several hundred individuals to fewer than 10. The ultimate origin of human society is in such groups. The photographs on this and next three pages are a rare group of pictures of baboons in the wild.

have covered the anthropoid apes, especially the gibbon and the chimpanzee (which are more closely related to man) as well as the New and Old World monkeys. On the human side the nearest contemporary approximations to the original cultural condition are societies of hunters and gatherers, preagricultural peoples exacting a meager livelihood from wild food resources. This cultural order dominated the Old Stone Age (one million to 10,000 or 15,000 years ago). Confidence in the comparative procedure which equates modern hunters and gatherers with the actual protagonists of the Stone Age is fortified by the remarkable social congruence observed among these peoples, even though they are historically as separated from one another as the Stone Age is distant from modern times. They include the Australian aborigines, the Bushmen of South Africa, the Andaman Islanders, the Shoshoni of the American Great Basin, the Eskimo, and Pygmy groups in Africa, Malaya and the Philippines.

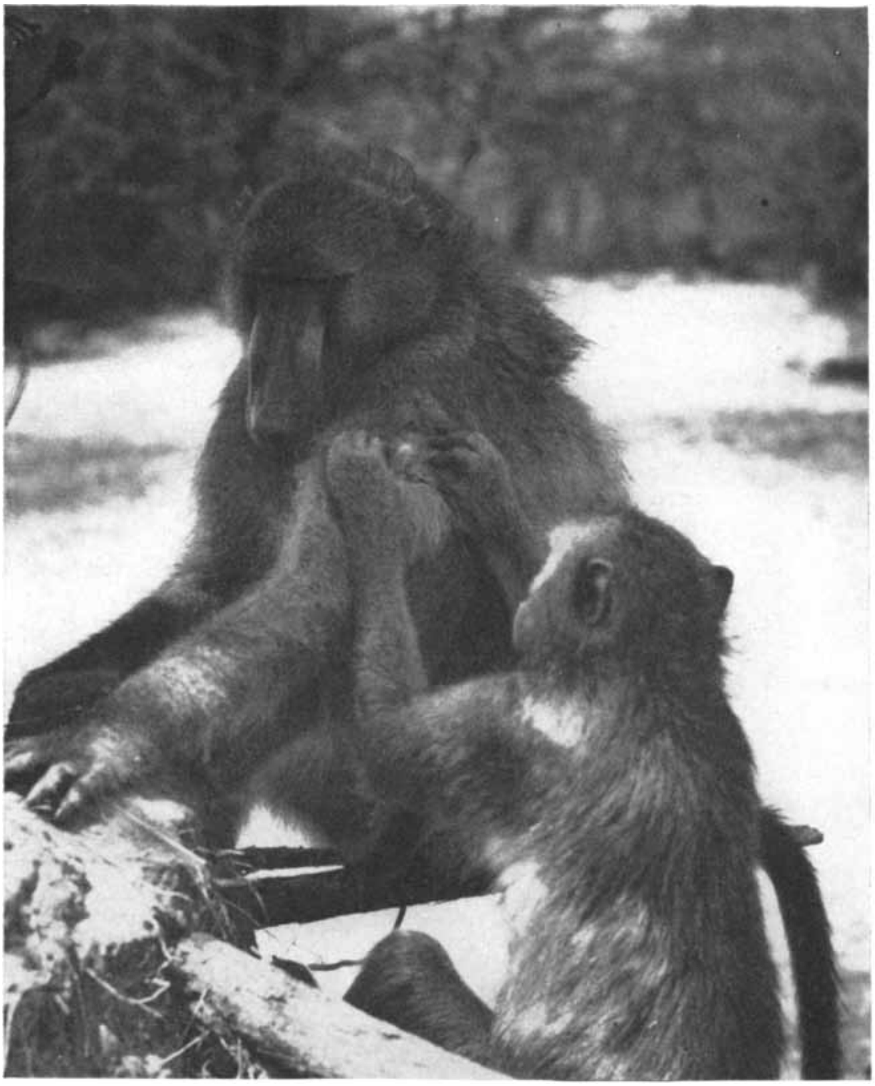
Comparison of primate sociology with the findings of anthropological research immediately suggests a startling conclusion: The way people act, and probably have always acted, is not the expression of inherent human nature. There is a quantum difference, at points a complete opposition, between even the most rudimentary human society and the most advanced subhuman primate one. The discontinuity implies that the emergence of human society required some suppression, rather than a direct expression, of man's primate nature. Human social life is culturally, not biologically, determined.

This is not to slander the poor apes, to suggest that their social behavior is necessarily innate and unlearned. Yet it is clearly the product of their nature, of animal needs and reactions, physiological processes and psychological responses. Their social life therefore varies directly with the organic constitution of the individual and the horde. In an unchanging environment the social characteristics of a given subhuman primate species are unchanging, unless or until the species is organically transformed. The same cannot be said about human social arrangements. We are all one species, but our social orders grow and diversify, even within a constant environment, and they do so quite apart from the minor biological (racial) differences that develop among different peoples.

This liberation of human society from direct biological control was its great evolutionary strength. Culture saved

CONSORT PAIR OF BABOONS forms near end of estrus, period of heightened sexual receptivity in female. At start of estrus she mates with several males, including juveniles.

MOTHER BABOON CARRIES INFANT while gathering food for herself. Unlike the human child, the baboon infant is obliged to gather its own food after it has been weaned.



MUTUAL GROOMING among baboons has several functions. Female (*top*) grooms male wounded in fight, removing blood and dirt from wound, which later healed perfectly. Mother baboon (*bottom*) grooms offspring, picking parasites and other objects from its coat.

man in his earliest days, clothed him, fed him and comforted him. In these times it has become possible to pile form on form in great social edifices that undertake to secure the survival of millions of people. Yet the remarkable aspect of culture's usurpation of the evolutionary task from biology was that in so doing it was forced to oppose man's primate nature on many fronts and to subdue it. It is an extraordinary fact that primate urges often become not the secure foundation of human social life, but a source of weakness in it.

The decisive battle between early culture and human nature must have been waged on the field of primate sexuality. The powerful social magnet of sex was the major impetus to subhuman primate sociability. This has long been recognized. But it was the British anatomist Sir Solly Zuckerman—whose attention to the matter developed from observation of the almost depraved behavior of baboons in zoos—who made sexuality the key issue of primate sociology. Subhuman primates are prepared to mate at all seasons, and although females show heightened receptivity midway through the menstrual cycle, they are often capable of sexual activity at other times. Most significantly for the assessment of its historic role, year-round sex in higher primates is associated with year-round heterosexual social life. Among other mammals sexual activity, and likewise heterosexual society, is frequently confined to a comparatively brief breeding season.

Of course other important social activities go on in the subhuman primate horde. Group existence confers advantages, such as defense against predation, which transcend the gratification of erotic urges. In the evolutionary perspective the intense, long-term sexuality of the primate individual is the historic complement of the advantages of horde life. Nor, in considering subhuman primate sexuality, should attention be confined to coitus. The evidence grows that certain Old World monkeys—the closely related baboon, rhesus monkey and Japanese monkey—do have seasonal declines in breeding without cessation of horde life. But sex enters into subhuman primate social relations in a variety of forms, and heterosexual copulation is only one of them. Sexual mounting is involved in the establishment of dominance, which grows out of chronic competition for food, mates and other desirable objects. It is a common element of youthful play; indeed, the female higher primate is unique among female mammals in displaying the adult sexual

YOUNG BABOONS PLAY around a tree. Two of the juveniles in the tree (*center*) are beginning to wrestle. Wrestling is one of the ways in which young baboons learn adult methods of fighting and plays an important role in their physical development.

DOMINANCE is illustrated as one male chases another, flashing his teeth and eyes in a combative expression. Establishment of dominance is a characteristic feature of life in a primate horde, and results from the continual competition for food and mates.

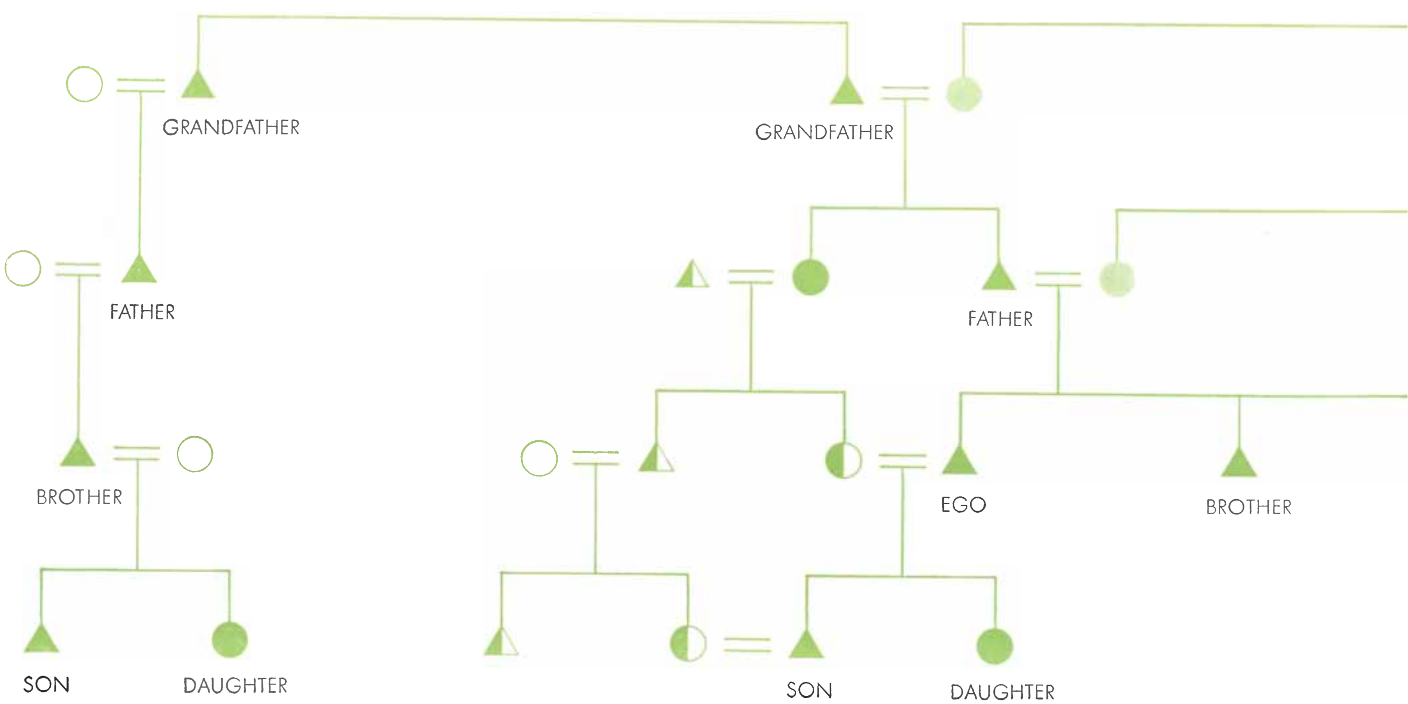
pattern prior to puberty. The familiar primate trait of mutual grooming—the pulling and licking out of parasites and other objects from the coat of another animal—often appears to be a secondary sexual activity. Sex is more than a force of attraction between adult males and females; it also operates among the young and between individuals of the same sex. Promiscuity is not an accurate term for it; it is indiscriminate. And while we might deem some of the forms perversions, to a monkey or an ape they are all just sociable.

Sex is not an unmitigated social blessing for primates. Competition over partners, for example, can lead to vicious, even fatal, strife. It was this side of primate sexuality that forced early culture to curb and repress it. The emerging human primate, in a life-and-death economic struggle with nature, could not afford the luxury of a social struggle. Co-operation, not competition, was essential. Culture thus brought primate sexuality under control. More than that, sex was made subject to regulations, such as the incest tabu, which effectively enlisted it in the service of co-operative kin relations. Among subhuman primates sex had organized society; the customs of hunters and gatherers testify eloquently that now society was to organize sex—in the interest of the economic adaptation of the group.

The evolution of the physiology of sex itself provided a basis for the cultural reorganization of social life. As Frank Beach of Yale University has pointed out, a progressive emancipation of sexuality from hormonal control runs through the primate order. This trend culminates in mankind, among whom sex is controlled more by the intellect—the cerebral cortex—than by glands. Thus it becomes possible to regulate sex by moral rules; to subordinate it to higher, collective ends. The consequent repression of primate sexuality in primitive as well as more developed societies has taken striking forms. In every human society sex is hedged by tabus: on time, place (the human animal alone demands privacy), on the sex and age of possible partners, on reference to sex in certain social contexts, on exposing the genitalia (particularly for females), on cohabitation during culturally important activities which range in different societies from war and ceremony to brewing beer. By way of an aside, it is notable that the repression of sex in favor of other ends is a battle which, while won for the species, is still joined in every individual to this day. In Sigmund Freud's famous allegory, the conflict between the self-seeking, sexually inclined id and the socially conscious superego re-enacts the development of culture that occurred in the remote past.

The design of many of these tabus is obvious: the disconcerting fascination of sex and its potentially disruptive consequences had to be eliminated from vital social activities. Thus the incest tabu is a guardian of harmony and solidarity within the family—a critical matter for hunters and gatherers, for among them the family is the fundamental economic as well as social group. At the same time, the injunction on sexual relations and marriage among close relatives necessarily forces different families into alliance and thus extends kinship and mutual aid.

It has been said that kinship, with its economic aspect of co-operation, became the plan for primitive human society. "Kinship" here means a cultural form, not a biological fact. Apes are of course genetically related to each other. But apes do not and cannot name and distinguish kinsmen, and they do not use kinship as a symbolic organization of behavior. On the other hand, cultural kinship has virtually nothing to do with biological connection. No one, for example, can be absolutely certain who his father is in a genetic sense, but in all human



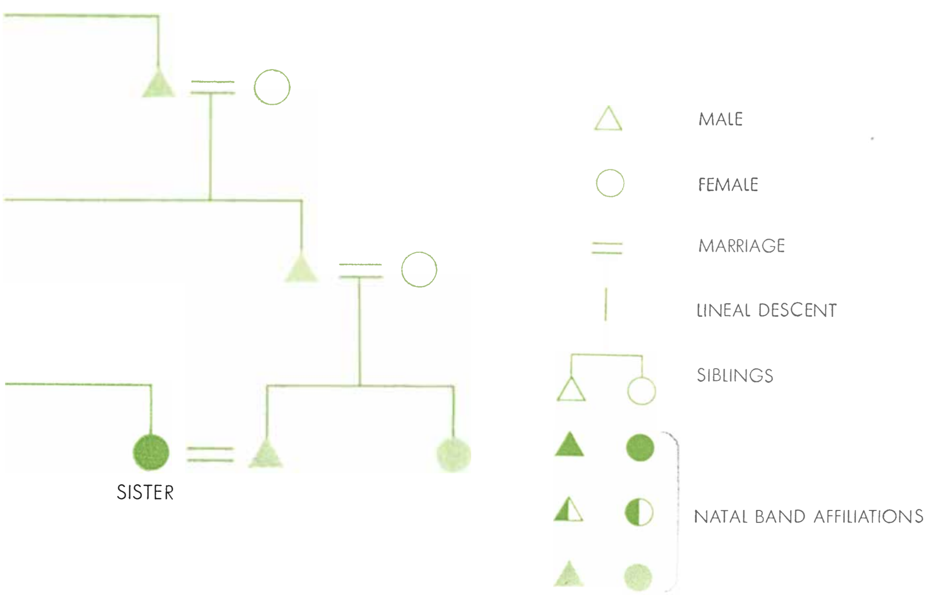
CONTROL OF PRIMATE URGES as achieved by early men through the reorganization of subhuman primate social life is illustrated in this model of kin and marriage relationships among primitive hunting and gathering peoples. Symbols are explained in key at right. Three pairs of symbols (*natal band affiliations*) represent three different bands. Blank symbols in diagram indicate members born in other bands. Kinship labels show relation of various members to the individual labeled "ego." Cross-cousin marriage (*i.e.,* marriage with the father's sister's child or the mother's brother's child) and residence in the husband's band after marriage are common customs among hunters and gatherers. Where these customs are followed, interband marriages are the societies fatherhood is a fundamental social status. Almost all societies adhere, implicitly or explicitly, to the dictum of the Napoleonic code in this respect: the father of the child is the husband of the mother.

Many hunters and gatherers carry kinship to an extreme that is curious to us. By a device technically known as classificatory kinship they ignore genealogical differences between collateral and lineal kin at certain points, lumping them terminologically and in social behavior. Thus my father's brother may be "father" to me, and I act accordingly. Close kinship may be extended indefinitely by the same logic: My father's brother's son is my "brother," my grandfather's brother is my "grandfather," his son is my "father," his son my "brother," and so on [see "Primitive Kinship," by Meyer Fortes; SCIENTIFIC AMERICAN, June, 1959]. As one observer remarked of the Australian aborigines: "It is impossible for an Australian native to have anything whatever to do with anyone who is not his relative, of one kind or another, near or distant."

The subhuman primate horde varies in size among different species, ranging from groups in the hundreds among certain Old World monkeys to the much smaller groups, often smaller than 10, characteristic of anthropoid apes. The horde may stay together all the time, or it may scatter during daytime feeding into packs of various sorts—mate groups of males and females, females with young, males alone—and come together again at night resting places. Monkeys seem inclined to scatter in this way more than apes.

There are typically more adult females than adult males within the horde, sometimes, as in the case of the howler monkey, three times as many. This may be in part due to a faster maturation rate for females. It may also reflect the elimination of some males in the course of competition for mates. These males are not necessarily killed. They may lead a solitary life outside or on the fringes of the horde, attempting all the while to attach themselves to some group and acquire sexual partners.

The progressive emancipation of sex from hormonal control in the primate order that was noted by Beach seems to be paralleled by a progressive development from promiscuous mating to the formation of exclusive, permanent heterosexual partnerships between specific animals. Among certain New World monkeys, females with their young comprise a separate pack within the horde,



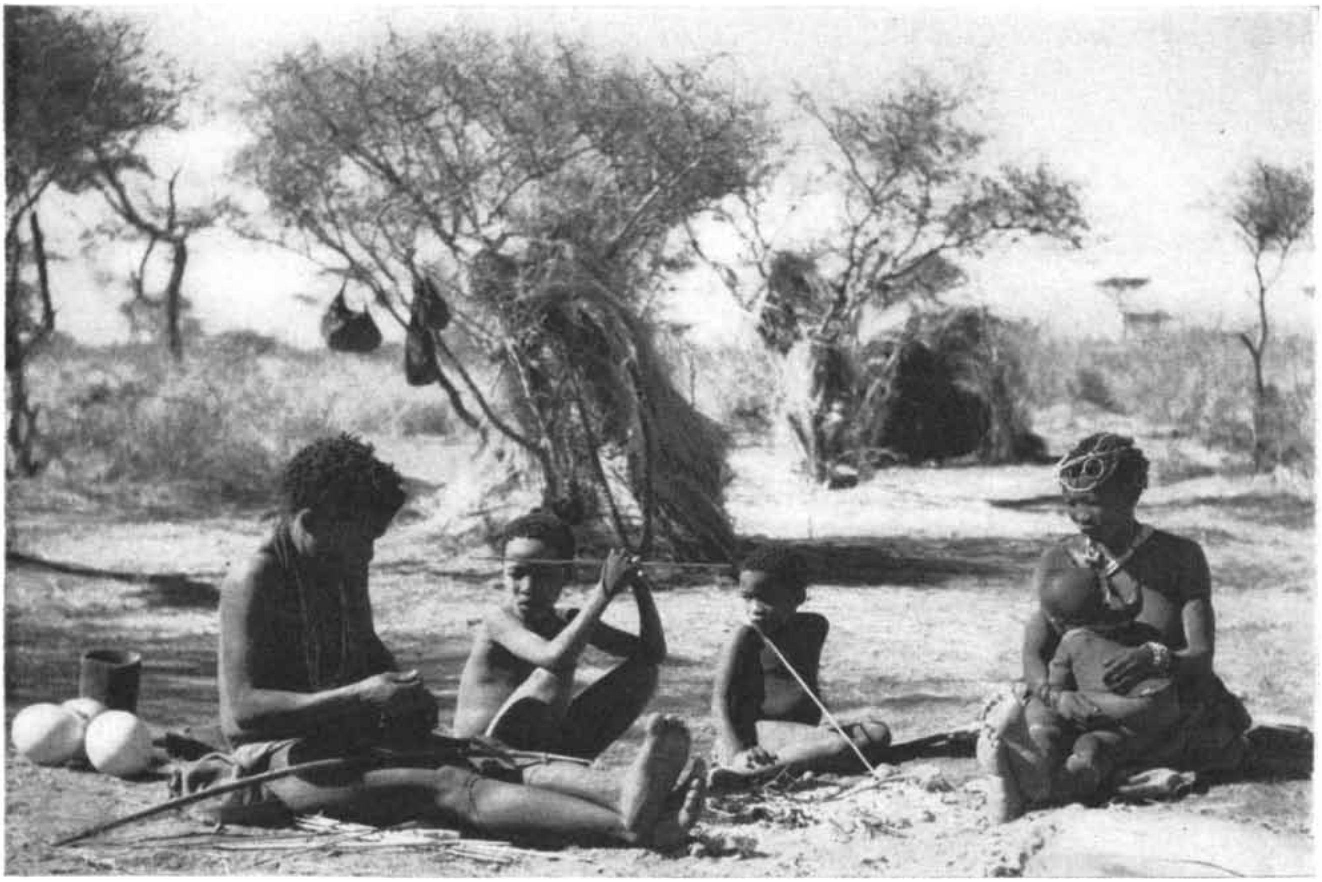
norm and supplement the incest tabu in eliminating competition for mates within the family and in promoting alliances among different families. A strong network of interfamily and interband kinship builds up generation after generation, widening and deepening the field of economic co-operation. At the same time that kinship is broadly extended, solidarity is maintained by use of a "classificatory" kinship terminology. Thus biologically distant relatives of "ego" may be socially equivalent to such close kin as father, brother and sister.

and only when a female is in heat does she forsake this group for males. She does not become attached to a specific male, but, wearing them out in turn, goes from one to another. The Old World rhesus horde and mate relations are similar except that a receptive female is taken over primarily by dominant males, a step in the direction of exclusiveness. In the anthropoid gibbon the trend toward exclusiveness is fully developed: the entire horde is typically composed of an adult male, a permanent female consort and their young. As yet it is not safe to state unequivocally that such progressive change runs through the entire primate order. It does appear that the higher subhuman primates presage the human family more than do the lower.

The primate horde is practically a closed social group. Each horde has a erritory, and local groups of most species defend their ground (or trees) against encroachment by others of their kind. The typical relation between adjacent hordes is that of enmity, especially, it seems, if food is short. Their borders are points of social deflection, and contact between neighbors is often marked by belligerent vocal cries, if it does not erupt into fatal violence.

Territorial relations among neighboring human hunting-and-gathering bands (a term used technically to refer to the cohesive local group) offer an instructive contrast. The band territory is never exclusive. Individuals and families may shift from group to group, especially in those habitats where food resources fluctuate from year to year and from place to place. In addition, a great deal of interband hospitality and visiting is undertaken for purely social and ceremonial reasons. Although bands remain autonomous politically, a general notion of tribalism, based on similarity in language and custom and on social collaboration, develops among neighboring groups. These tendencies are powerfully reinforced by kinship and the cultural regulation of sex and marriage. Among all modern survivors of the Stone Age, marriage with close relatives is forbidden, while marriage outside the band is at least preferred and sometimes morally prescribed. The kin ties thereby created become social pathways of mutual aid and solidarity connecting band to band. It does not seem unwarranted to assert that the human capacity to extend kinship was a necessary social condition for the deployment of early man over the great expanses of the planet.

Another implication of interband kin-



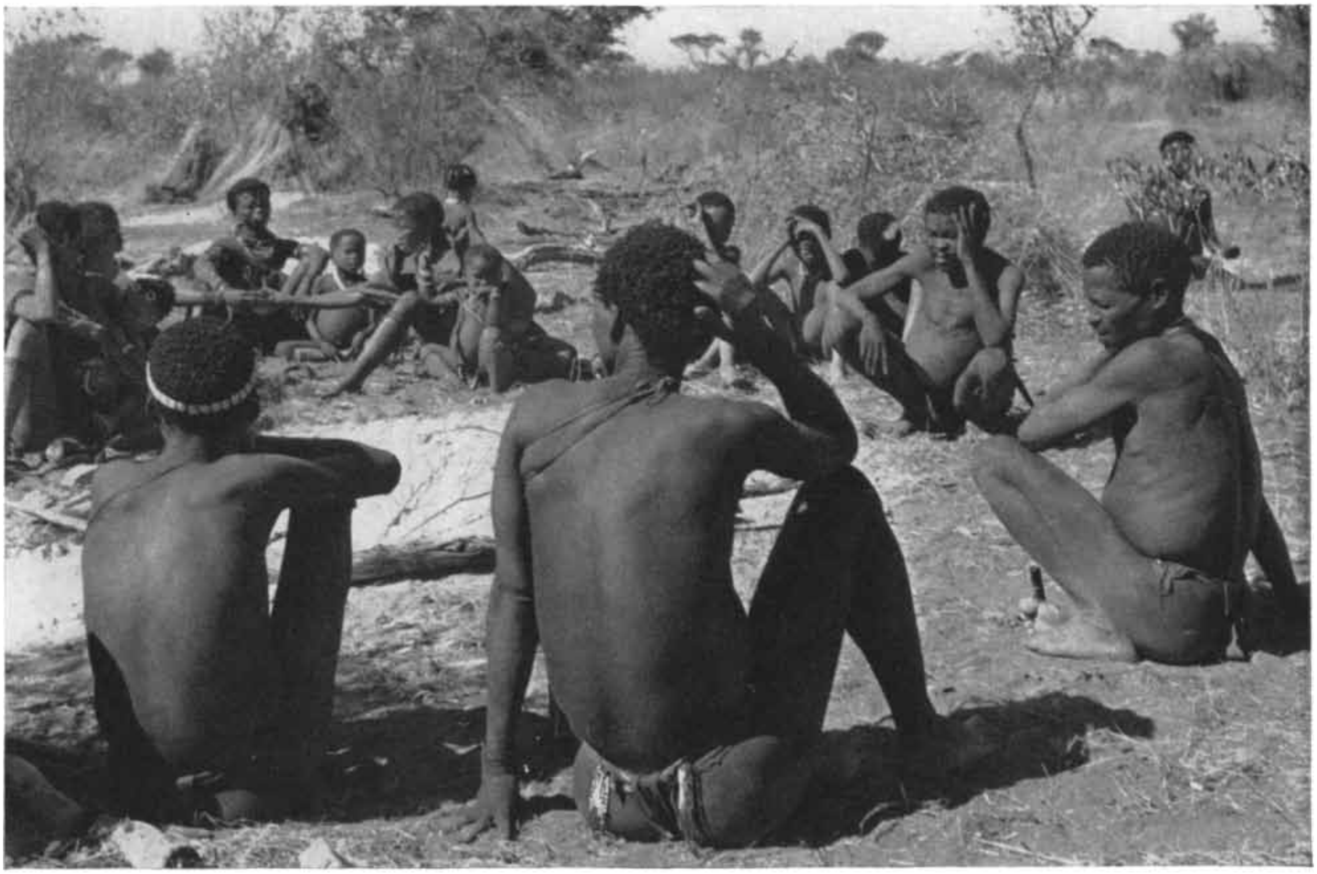
KUNG BUSHMAN AND HIS FAMILY sit at fire in Kalahari Desert Basin of Southwest Africa. Kung society, one of the most primitive now extant, may resemble society of early men. Among Kung, family is basic subsistence unit. Photographs on these and next four pages were made by the seven expeditions of the Peabody Museum of Harvard University to Southwest Africa, 1950-1959, led by Laurence K. Marshall. The 1952, 1956 and subsequent expeditions were jointly sponsored by the Smithsonian Institution.

ship deserves emphasis: Warfare is limited among hunters and gatherers. Indeed, many are reported to find the idea of war incomprehensible. A massive military effort would be difficult to sustain for technical and logistic reasons. But war is even further inhibited by the spread of a social relation—kinship—which in primitive society is often a synonym for "peace." Thomas Hobbes's famous fantasy of a war of "all against all" in the natural state could not be further from the truth. War increases in intensity, bloodiness, duration and significance for social survival through the evolution of culture, reaching its culmination in modern civilization. Paradoxically the cruel belligerence that is popularly considered the epitome of human nature reaches its zenith in the human condition most removed from the pristine. By contrast, it has been remarked of the Bushmen that "it is not in their nature to fight."

The only permanent organization within the band is the family, and the band is a grouping of related families, on the average 20 to 50 people altogether. Bands lack true government and law; the rules of good order are synonymous with customs of proper behavior toward kinsmen. In certain ways this system of etiquette is even more effective than law. A breach of etiquette cannot go undetected, and punishment in the form of avoidance, gossip and ridicule follows hard upon offense.

The primitive human family, unlike the subhuman primate mate group, is not based simply on sexual attraction. Sex is easily available in many band societies, both before and outside marriage, but this alone does not necessarily create or destroy the family. The incest tabu itself implies that the human family cannot be the social outcome of erotic urges. Moreover, sexual rights to a wife may even be waived in the interest of securing friendly relations with other men, as in the famous Eskimo custom of wife lending. This, incidentally, is only one cultural device among many for enlisting marriage and sex in the creation of wide social alliance. In remarkable contrast to subhuman primate unions, often created and maintained in violence, marriage is in band society a means of securing peace. Adultery and quarrels over women are not unknown among primitive peoples. But such actions are explicitly considered antisocial. Among monkeys and apes, on the other hand, comparable events create the social order.

Marriage and the family are institutions too important in primitive life to be built on the fragile, shifting foundations of "love." The family is the decisive economic institution of society. It is to the hunter and gatherer what the manor was to feudal Europe, or the corporate factory system is to capitalism: it is the productive organization. The primary division of labor in band economy is that between men and women. The men typically hunt and make weapons; the women gather wild plants and take care of the home and children. Marriage then is an alliance between the two essential social elements of production. These factors complement each other—the Eskimos say: "A man is the hunter his wife makes him"—and they lock their possessors in enduring marital and fa-



EXTENDED FAMILY in Kung society may include sons with their daughters, and daughters with their husbands. In the extended family shown here, three sons-in-law are in foreground. The father, Gao Hunchback (*hand to face*) is headman of his band, which in this case consists of the one family. About 1,000 Kung, grouped into 28 separate bands, live in 10,000 square miles of Nyae Nyae region of Kalahari Basin. Each band has its own territory. Bands intermarry and visit one another throughout region.

milial relations. Many anthropologists have testified that in the minds of the natives the ability to cook and sew or to hunt are much more important than is beauty in a prospective spouse.

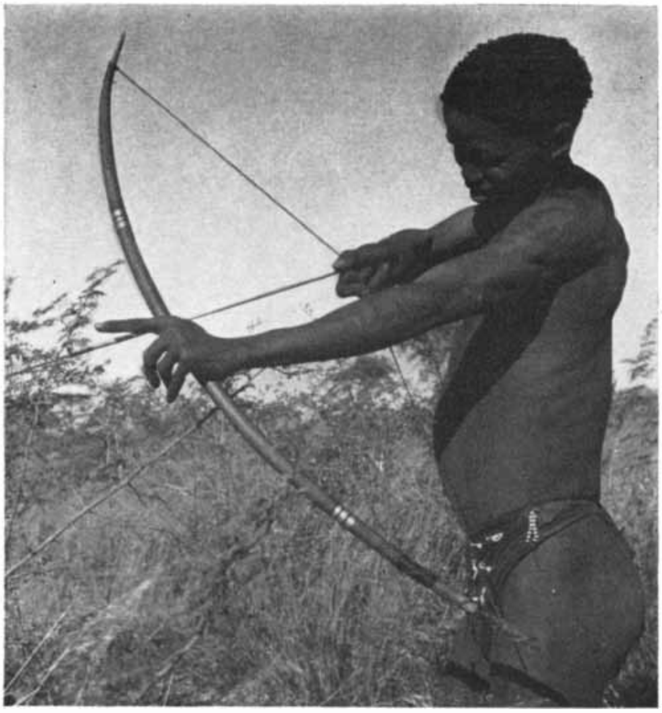
The economic aspect of primitive marriage is responsible for many of its specific characteristics. For one thing, it is the normal adult state; one cannot economically afford to remain single. Hence the solitary subhuman primate male has no counterpart in the primitive band. The number of spouses is, however, limited by economic considerations among primitives. A male ape has as many mates as it can get and defend for itself; a man, no more than he can support. In fact, marriage is usually monogamous among hunters and gatherers, although there are normally no rules against polygamy. Culture, reflecting the compulsions of economics, thus dramatically altered human mating and differentiated the human family from its nearest primate analogues.

"Peck orders" of dominance and subordination are characteristic of subhuman primate social relations. Chronic competition for mates and perhaps food or other desirable objects establishes and maintains such hierarchies in every grouping of monkeys and apes. Repeated victory secures future privileges for a dominant animal; subordinates, by conditioned response, withdraw from or yield access to anything worth having. As Henry W. Nissen of the Yerkes Laboratories of Primate Biology has observed, "the bigger animal gets most of the food; the stronger male, most of the females." In most species males tend to dominate over females, although in certain anthropoid apes, notably the chimpanzee and the gibbon, the reverse can occur. A difference in what has been called dominance quality seems to arise between primate suborders: in New World monkeys, dominance is "tenuous"; in Old World monkeys it may become "rough" and "brutal"; in apes, while clearly apparent, it is not so violently established or sustained. In all species, however, dominance affects a variety of social activities, including play, grooming and interhorde relations as well as sex and feeding.

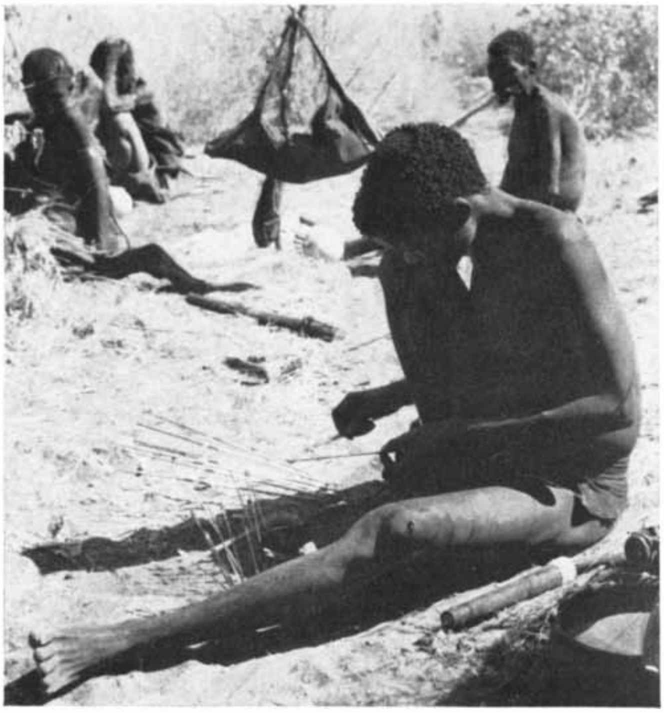
Compared both to subhuman primate antecedents and to subsequent cultural developments, dominance is at its nadir among primitive hunters and gatherers. Culture is the oldest "equalizer." Among animals capable of symbolic communication, the weak can always collectively connive to overthrow the strong. On the other side, political and economic means of tyranny remain underdeveloped among hunters and gatherers.

There is some evolutionary continuity in dominance behavior from primate to primitive; among hunters and gatherers leadership, such as it is, falls to men. Yet the supremacy of men in the band as a whole does not necessarily mean the abject subordination of women in the home. Once more the weapon of articulate speech must be reckoned with; the Danish anthropologist Kaj Birket-Smith observes: "A census would certainly show a higher percentage of henpecked husbands among the Eskimos than in a civilized country (except, perhaps, the U. S.!); most Eskimos have a deeply rooted respect for their wives' tongues."

The men who lead the band are the



OCCUPATIONS OF KUNG MEN are shown at top of these two pages. Here a hunter uses chief weapons: bow and poisoned arrows.



ARROWS ARE POISONED by another hunter. Poison comes from a beetle grub and is sometimes mixed with poison pods or roots.

wiser and older. They are not, however, respected for their ability to commandeer limited supplies of desired goods. On the contrary, generosity is a necessary qualification for prestige; the man who does most for the band, who sacrifices most, will be the one most loved and heeded by the rest. The test of status among hunters and gatherers is usually the reverse of that among monkeys and apes; it is a matter of who gives away, not who takes away. A second qualification for leadership is knowledge—knowledge of ritual, tradition, game movements, terrain and the other things that control social life. This is why older men are respected. In a stable society they know more than the others, and to be "old-fashioned" is a great virtue.

Knowledge of itself breeds little power. The headmen of a band can rule only

OCCUPATIONS OF KUNG WOMEN are shown in photographs at bottom of these two pages. The basic occupation of women is gathering of food. Kung woman above has gathered enough tsi nuts in her kaross (*lower left*) to supply her needs for several days.

KUNG MAN STRETCHES HIDE prior to scraping and softening it. He will then make garments and carrying bags from the hide.

BUILDING FIRES is also the duty of Kung men. Since the women are gatherers, they collect the wood, though men often help.

by advice, not by fiat. As a Congo Pygmy leader bluntly remarked to an anthropologist, there is just no point in giving orders, "as nobody would heed them." The titles of reference given leaders of hunting and gathering bands speak eloquently of their powers: the Shoshoni leader is "the talker," and his Eskimo counterpart is "he who thinks." In a primitive band each family is a more cohesive, stronger polity than the band as a whole, and each is free to manage its own affairs. Birket-Smith said: "There is no rank or class among the Eskimos, who must therefore renounce that satisfaction, which Thackeray calls the true pleasure of life, of associating with one's inferiors." The same may be said of other primitive societies.

The leveling of the social order that accompanied the development of culture

BUILDING SCHERMS (protective shelters) from branches and grass is another part of Kung women's work, since it is associated with food-gathering activities. White object at left is a hide that has been scraped by husband of woman shown building scherm.

KUNG BABIES ARE NURSED by their mothers. Naoka (*foreground*) is first wife of Ti Kay, a headman. Nai (*background*) is Naoka's sister and Ti Kay's second wife.

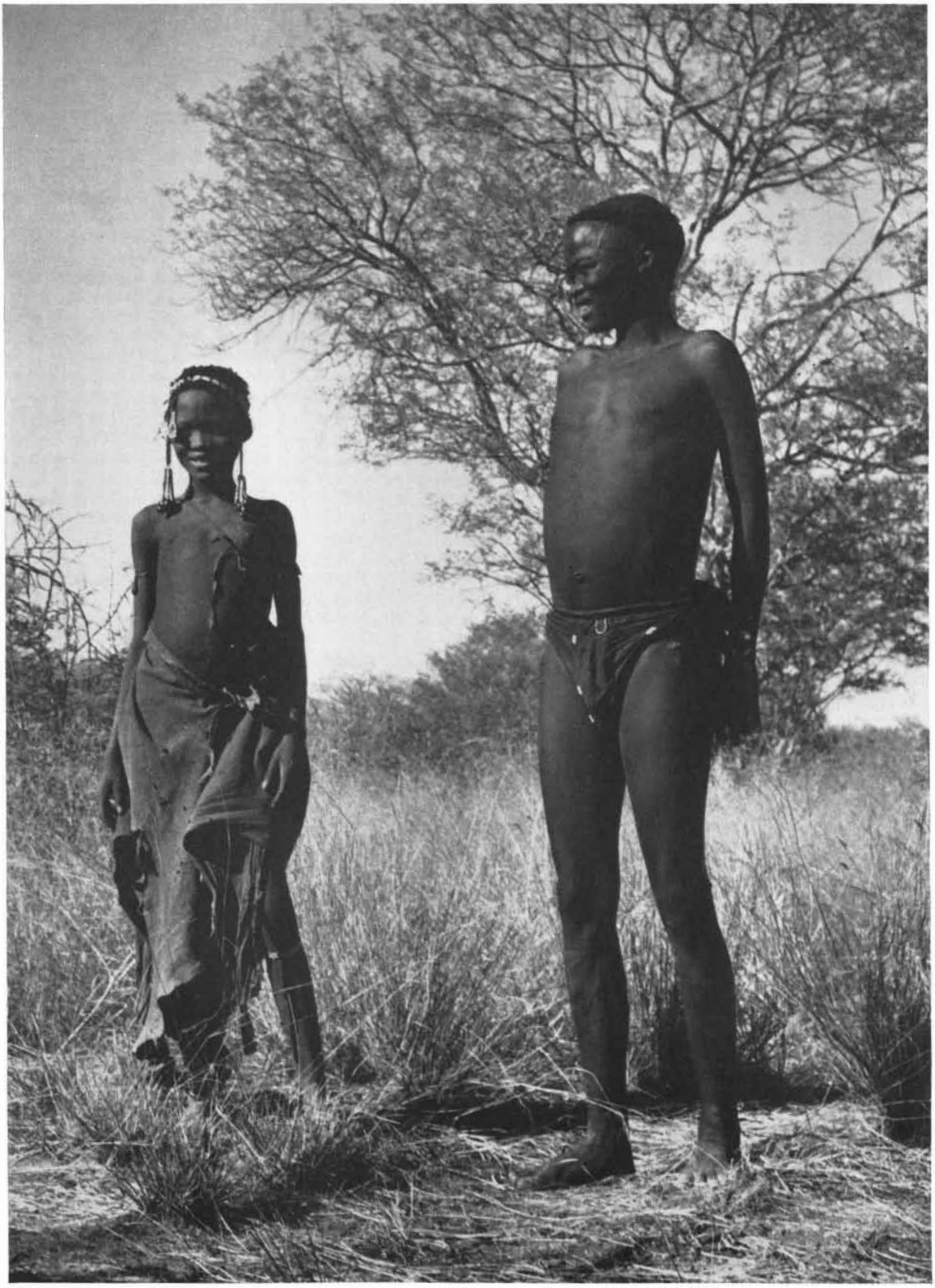
SMALL KUNG GIRL GROOMS another. She is looking for lice, which she eats. Among the Kung, as among subhuman primates, grooming is an ancillary food-gathering activity.

is related to the fundamental economic change from the selfish—literally rugged—individualism of the primate to co-operative kin dealings. Monkeys and apes do not co-operate economically; monkeys cannot even be taught by humans to work together, although apes can. Nor is food ever shared except in the sense that a subordinate animal may be intimidated into handing it over to a dominant one. Among primitives, on the other hand, food sharing follows automatically from the division of labor by sex. More than that, the family economy is a pooling of goods and services—"communism in living" as a famous 19th-century anthropologist called it. Mutual aid is extended far beyond the family. It is a demand of group survival that the successful hunter be prepared to share his spoils with the unsuccessful. "The hunter kills, other people have," say the Yukaghir of Siberia.

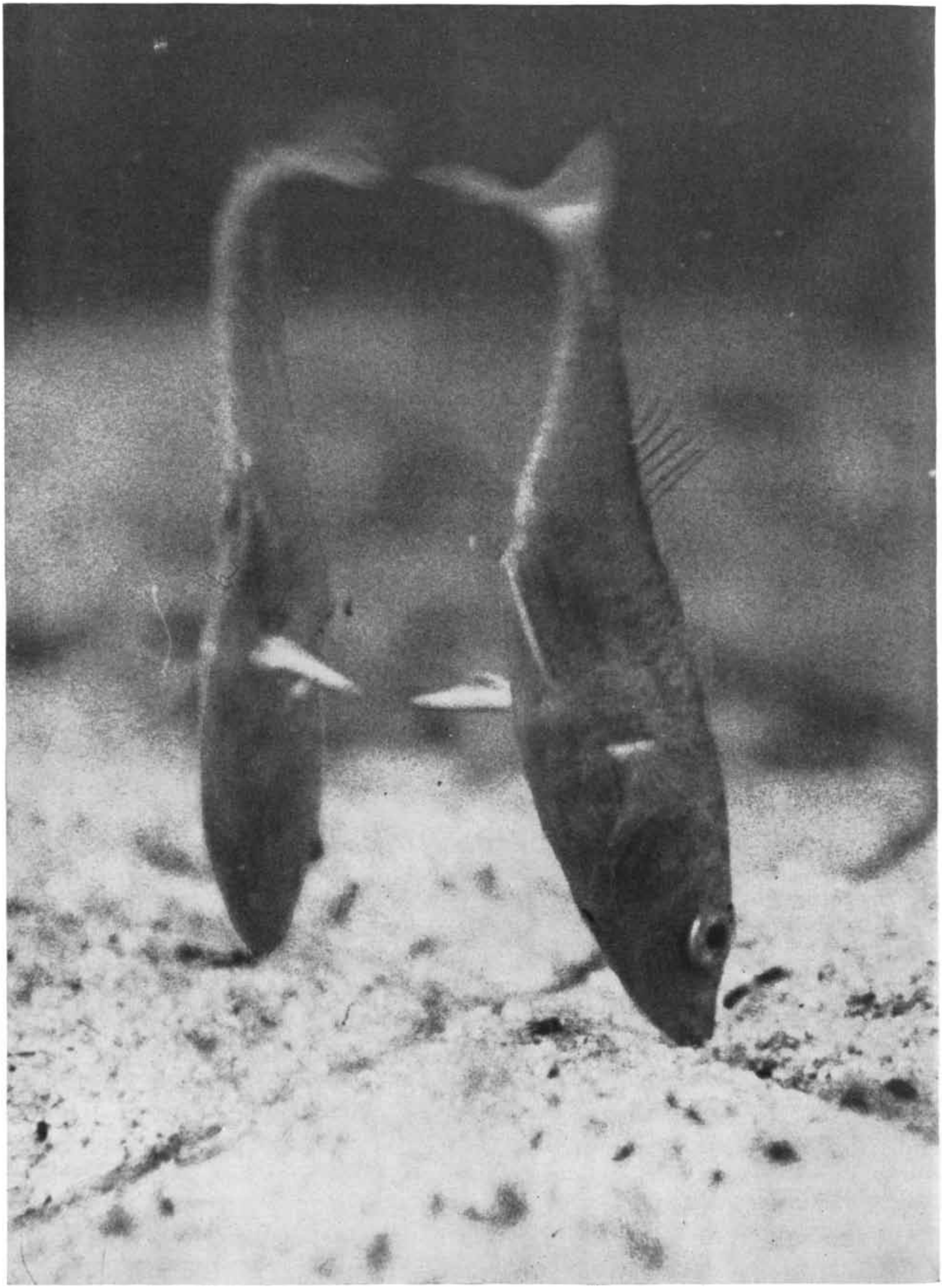
In a band economy goods commonly pass from hand to hand, and the circulation gains momentum in proportion to the degree of kinship among households and the importance of the goods for survival. Food, the basic resource, must always be made available to others on pain of ostracism; the scarcer it becomes, the more readily it must be given away, and for nothing. In addition, food and other things are often shared to promote friendly relations, utilitarian considerations notwithstanding. There was a time in human affairs when the only right of property that brought honor was that of giving it away.

The economic behavior of primitives obviously does not conform to the stereotype of "economic man" by which we organize and analyze our own economy. But it does conform to a realm of economics familiar to us, so familiar that no one bothers to talk about it and it lacks an economic science: kinship-friendship economics. There is much to be learned about primitive economics here, and it would not be a mere exercise in analogy, for our kin life is the evolutionary survival of relations that once encompassed society itself.

In selective adaptation to the perils of the Stone Age, human society overcame or subordinated such primate propensities as selfishness, indiscriminate sexuality, dominance and brute competition. It substituted kinship and co-operation for conflict, placed solidarity over sex, morality over might. In its earliest days it accomplished the greatest reform in history, the overthrow of human primate nature, and thereby secured the evolutionary future of the species.



YOUNG MARRIED COUPLE, Tsamgao and his wife Bau, stand at the edge of a Kung campsite. Kung Bushman girls are often married several years before they reach puberty. Boys usually marry in their teens, after they have proved themselves as hunters.



THREAT POSTURE of male stickleback is example of nonvocal communication in lower animals. In this picture, made by N. Tinbergen of the University of Oxford, the fish is responding to its mirror image by indicating readiness to fight "intruding" male.

The Origin of Speech

Man is the only animal that can communicate by means of abstract symbols. Yet this ability shares many features with communication in other animals, and has arisen from these more primitive systems

by Charles F. Hockett

About 50 years ago the Linguistic Society of Paris established a standing rule barring from its sessions papers on the origin of language. This action was a symptom of the times. Speculation about the origin of language had been common throughout the 19th century, but had reached no conclusive results. The whole enterprise in consequence had come to be frowned upon—as futile or crackpot—in respectable linguistic and philological circles. Yet amidst the speculations there were two well-reasoned empirical plans that deserve mention even though their results were negative.

A century ago there were still many corners of the world that had not been visited by European travelers. It was reasonable for the European scholar to suspect that beyond the farthest frontiers there might lurk half-men or man-apes who would be "living fossils" attesting to earlier stages of human evolution. The speech (or quasi-speech) of these men (or quasi-men) might then similarly attest to earlier stages in the evolution of language. The search was vain. Nowhere in the world has there been discovered a language that can validly and meaningfully be called "primitive." Edward Sapir wrote in 1921: "There is no more striking general fact about language than its universality. One may argue as to whether a particular tribe engages in activities that are worthy of the name of religion or of art, but we know of no people that is not possessed of a fully developed language. The lowliest South African Bushman speaks in the forms of a rich symbolic system that is in essence perfectly comparable to the speech of the cultivated Frenchman."

The other empirical hope in the 19th century rested on the comparative method of historical linguistics, the discovery of which was one of the triumphs of the period. Between two languages the resemblances are sometimes so extensive and orderly that they cannot be attributed to chance or to parallel development. The alternative explanation is that the two are divergent descendants of a single earlier language. English, Dutch, German and the Scandinavian languages are related in just this way. The comparative method makes it possible to examine such a group of related languages and to construct, often in surprising detail, a portrayal of the common ancestor, in this case the proto-Germanic language. Direct documentary evidence of proto-Germanic does not exist, yet understanding of its workings exceeds that of many languages spoken today.

There was at first some hope that the comparative method might help determine the origin of language. This hope was rational in a day when it was thought that language might be only a few thousands or tens of thousands of years old, and when it was repeatedly being demonstrated that languages that had been thought to be unrelated were in fact related. By applying the comparative method to all the languages of the world, some earliest reconstructable horizon would be reached. This might not date back so early as the origin of language, but it might bear certain earmarks of primitiveness, and thus it would enable investigators to extrapolate toward the origin. This hope also proved vain. The earliest reconstructable stage for any language family shows all the complexities and flexibilities of the languages of today.

These points had become clear a half-century ago, by the time of the Paris ruling. Scholars cannot really approve of such a prohibition. But in this instance it had the useful result of channeling the energies of investigators toward the gathering of more and better information about languages as they are today. The subsequent progress in understanding the workings of language has been truly remarkable. Various related fields have also made vast strides in the last half-century: zoologists know more about the evolutionary process, anthropologists know more about the nature of culture, and so on. In the light of these developments there need be no apology for reopening the issue of the origins of human speech.

Although the comparative method of linguistics, as has been shown, throws no light on the origin of language, the investigation may be furthered by a comparative method modeled on that of the zoologist. The frame of reference must be such that all languages look alike when viewed through it, but such that within it human language as a whole can be compared with the communicative systems of other animals, especially the other hominoids, man's closest living relatives, the gibbons and great apes. The useful items for this sort of comparison cannot be things such as the word for "sky"; languages have such words, but gibbon calls do not involve words at all. Nor can they be even the signal for "danger," which gibbons do have. Rather, they must be the basic features of design that can be present or absent in any communicative system, whether it be a communicative system of humans, of animals or of machines.

With this sort of comparative method it may be possible to reconstruct the communicative habits of the remote ancestors of the hominoid line, which may be called the protohominoids. The task, then, is to work out the sequence by which that ancestral system became language as the hominids—the man-apes and ancient men—became man.

A set of 13 design-features is presented in the illustration on the opposite page. There is solid empirical justification for the belief that all the languages of the world share every one of them. At first sight some appear so trivial that no one looking just at language would bother to note them. They become worthy of mention only when it is realized that certain animal systems—and certain human systems other than language—lack them.

The first design-feature—the "vocal-auditory channel"—is perhaps the most obvious. There are systems of communication that use other channels; for example, gesture, the dancing of bees or the courtship ritual of the stickleback. The vocal-auditory channel has the advantage—at least for primates—that it leaves much of the body free for other activities that can be carried on at the same time.

The next two design-features—"rapid fading" and "broadcast transmission and directional reception," stemming from the physics of sound—are almost unavoidable consequences of the first. A linguistic signal can be heard by any auditory system within earshot, and the source can normally be localized by binaural direction-finding. The rapid fading of such a signal means that it does not linger for reception at the hearer's convenience. Animal tracks and spoors, on the other hand, persist for a while; so of course do written records, a product of man's extremely recent cultural evolution.

The significance of "interchangeability" and "total feedback" for language becomes clear upon comparison with other systems. In general a speaker of a language can reproduce any linguistic message he can understand, whereas the characteristic courtship motions of the male and female stickleback are different, and neither can act out those appropriate to the other. For that matter in the communication of a human mother and infant neither is apt to transmit the characteristic signals or to manifest the typical responses of the other. Again, the speaker of a language hears, by total feedback, everything of linguistic relevance in what he himself says. In contrast, the male stickleback does not see the colors of his own eye and belly that are crucial in stimulating the female. Feedback is important, since it makes possible the so-called internalization of communicative behavior that constitutes at least a major portion of "thinking."

The sixth design-feature, "specialization," refers to the fact that the bodily effort and spreading sound waves of speech serve no function except as signals. A dog, panting with his tongue hanging out, is performing a biologically essential activity, since this is how dogs cool themselves off and maintain the proper body temperature. The panting dog incidentally produces sound, and thereby may inform other dogs (or humans) as to where he is and how he feels. But this transmission of information is strictly a side effect. Nor does the dog's panting exhibit the design-feature of "semanticity." It is not a signal meaning that the dog is hot; it is part of being hot. In language, however, a message triggers the particular result it does because there are relatively fixed associations between elements in messages (*e.g.*, words) and recurrent features or situations of the world around us. For example, the English word "salt" means salt, not sugar or pepper. The calls of gibbons also possess semanticity. The gibbon has a danger call, for example, and it does not in principle matter that the meaning of the call is a great deal broader and more vague than, say, the cry of "Fire!"

In a semantic communicative system the ties between meaningful message-elements and their meanings can be arbitrary or nonarbitrary. In language the ties are arbitrary. The word "salt" is not salty nor granular; "dog" is not "canine"; "whale" is a small word for a large object; "microorganism" is the reverse. A picture, on the other hand, looks like what it is a picture of. A bee dances faster if the source of nectar she is reporting is closer, and slower if it is farther away. The design-feature of "arbitrariness" has the disadvantage of being arbitrary, but the great advantage that there is no limit to what can be communicated about.

Human vocal organs can produce a huge variety of sound. But in any one language only a relatively small set of ranges of sound is used, and the differences between these ranges are functionally absolute. The English words "pin" and "bin" are different to the ear only at one point. If a speaker produces a syllable that deviates from the normal pronunciation of "pin" in the direction of that of "bin," he is not producing still a third word, but just saying "pin" (or perhaps "bin") in a noisy way. The hearer compensates if he can, on the basis of context, or else fails to understand. This feature of "discreteness" in the elementary signaling units of a language contrasts with the use of sound effects by way of vocal gesture. There is an effectively continuous scale of degrees to which one may raise his voice as in anger, or lower it to signal confidentiality. Bee-dancing also is continuous rather than discrete.

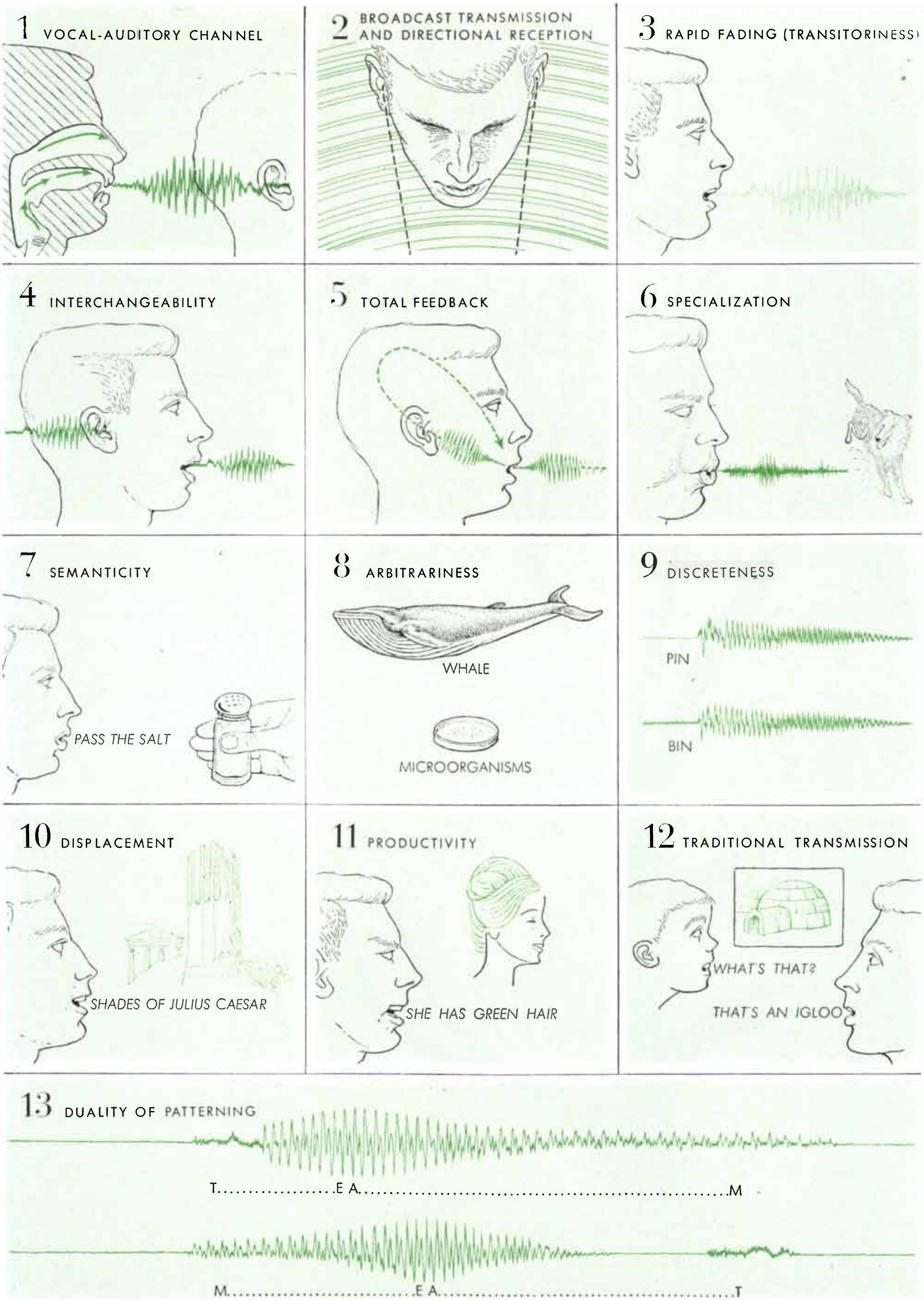
Man is apparently almost unique in being able to talk about things that are remote in space or time (or both) from where the talking goes on. This feature—"displacement"—seems to be definitely lacking in the vocal signaling of man's closest relatives, though it does occur in bee-dancing.

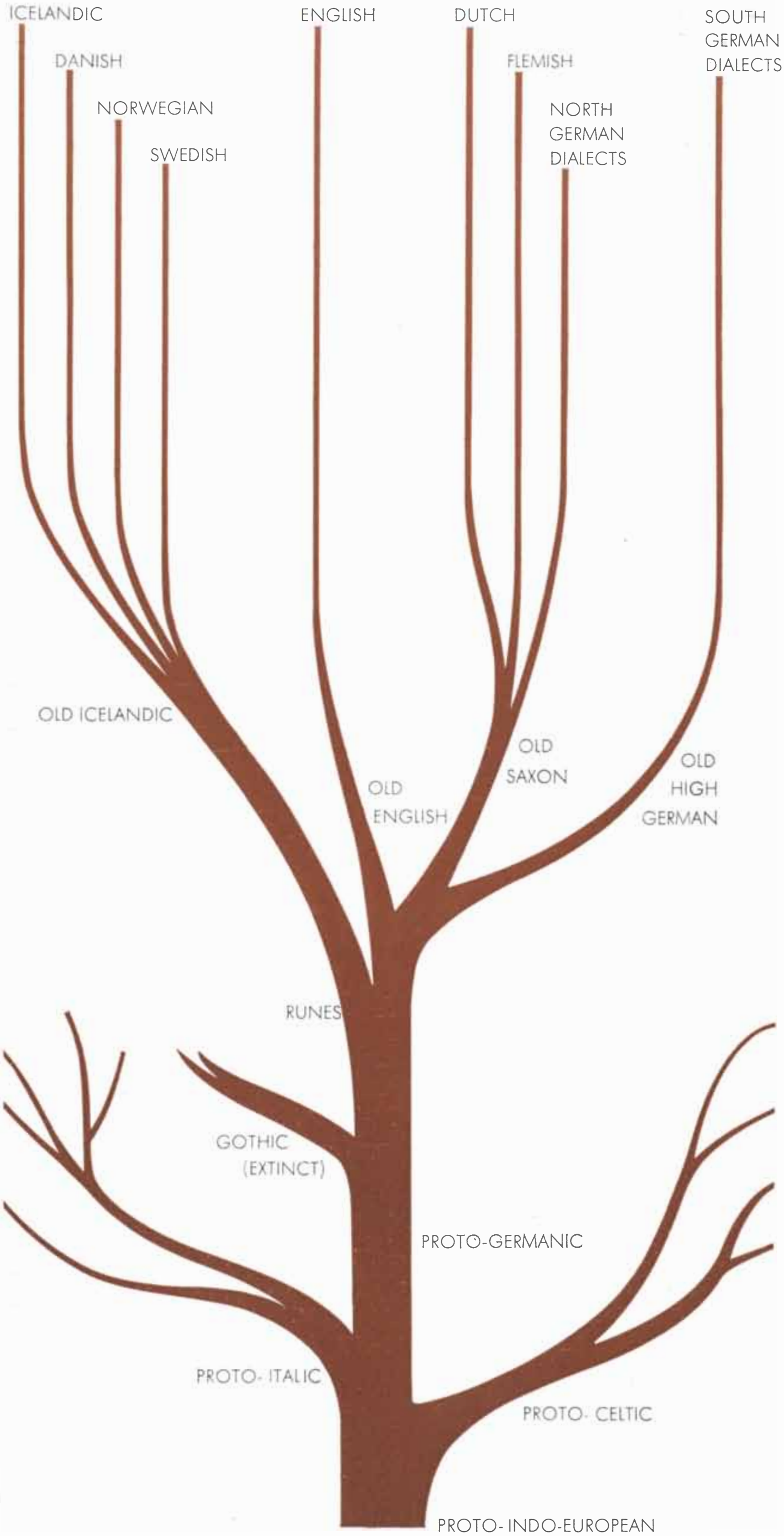
One of the most important design-features of language is "productivity"; that is, the capacity to say things that have never been said or heard before and yet to be understood by other speakers of the language. If a gibbon makes any vocal sound at all, it is one or another of a small finite repertory of familiar calls. The gibbon call system can be characterized as closed. Language is open, or "productive," in the sense that one can coin new utterances by putting together pieces familiar from old utterances, assembling them by patterns of arrangement also familiar in old utterances.

Human genes carry the capacity to acquire a language, and probably also a strong drive toward such acquisition, but the detailed conventions of any one language are transmitted extragenetically by learning and teaching. To what extent such "traditional transmission" plays a part in gibbon calls or for other mammalian systems of vocal signals is not known, though in some instances the uniformity of the sounds made by a species, wherever the species is found over the world, is so great that genetics must be responsible.

The meaningful elements in any language—"words" in everyday parlance, "morphemes" to the linguist—constitute an enormous stock. Yet they are represented by small arrangements of a relatively very small stock of distinguishable sounds which are in themselves wholly meaningless. This "duality of patterning" is illustrated by the English words

THIRTEEN DESIGN-FEATURES of animal communication, discussed in detail in the text of this article, are symbolized on opposite page. The patterns of the words "pin," "bin," "team" and "meat" were recorded at Bell Telephone Laboratories.


1 VOCAL-AUDITORY CHANNEL
2 BROADCAST TRANSMISSION AND DIRECTIONAL RECEPTION
3 RAPID FADING (TRANSITORINESS)
4 INTERCHANGEABILITY
5 TOTAL FEEDBACK
6 SPECIALIZATION
7 SEMANTICITY
PASS THE SALT
8 ARBITRARINESS
WHALE
MICROORGANISMS
9 DISCRETENESS
PIN
BIN
10 DISPLACEMENT
SHADES OF JULIUS CAESAR
11 PRODUCTIVITY
SHE HAS GREEN HAIR
12 TRADITIONAL TRANSMISSION
WHAT'S THAT?
THAT'S AN IGLOO
13 DUALITY OF PATTERNING
T..................E A...M
M...........................E A...T



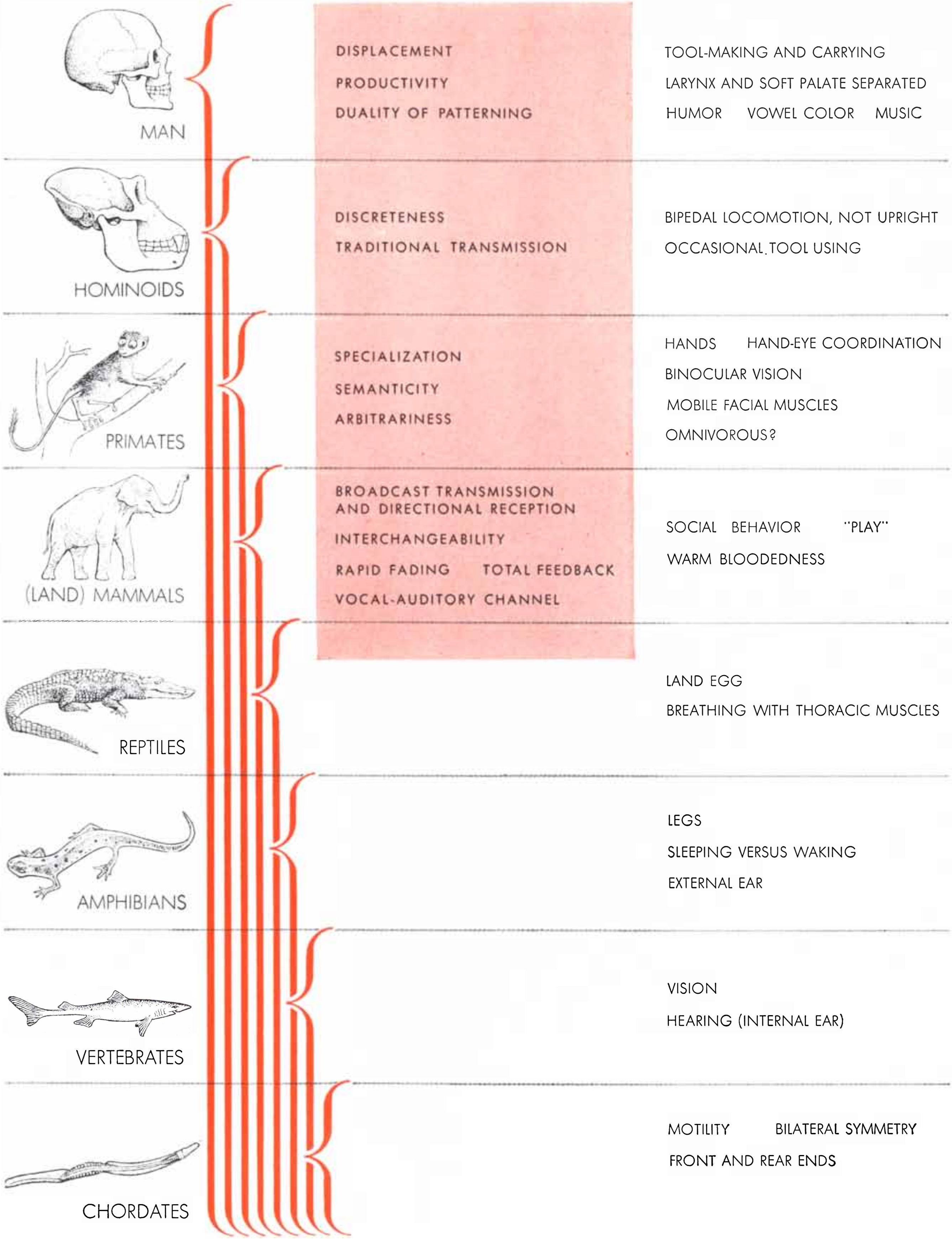
ORIGIN OF MODERN GERMANIC LANGUAGES, as indicated by this "family tree," was proto-Germanic, spoken some 2,700 years ago. Comparison of present-day languages has provided detailed knowledge of proto-Germanic, although no direct documentary evidence for the language exists. It grew, in turn, from the proto-Indo-European of 5000 B.C. Historical studies cannot, however, trace origins of language back much further in time.

"tack," "cat" and "act." They are totally distinct as to meaning, and yet are composed of just three basic meaningless sounds in different permutations. Few animal communicative systems share this design-feature of language—none among the other hominoids, and perhaps none at all.

It should be noted that some of these 13 design-features are not independent. In particular, a system cannot be either arbitrary or nonarbitrary unless it is semantic, and it cannot have duality of patterning unless it is semantic. It should also be noted that the listing does not attempt to include all the features that might be discovered in the communicative behavior of this or that species, but only those that are clearly important for language.

It is probably safe to assume that nine of the 13 features were already present in the vocal-auditory communication of the protohominoids—just the nine that are securely attested for the gibbons and humans of today. That is, there were a dozen or so distinct calls, each the appropriate vocal response (or vocal part of the whole response) to a recurrent and biologically important type of situation: the discovery of food, the detection of a predator, sexual interest, need for maternal care, and so on. The problem of the origin of human speech, then, is that of trying to determine how such a system could have developed the four additional properties of displacement, productivity and full-blown traditional transmission. Of course the full story involves a great deal more than communicative behavior alone. The development must be visualized as occurring in the context of the evolution of the primate horde into the primitive society of food-gatherers and hunters, an integral part, but a part, of the total evolution of behavior.

It is possible to imagine a closed system developing some degree of productivity, even in the absence of the other three features. Human speech exhibits a phenomenon that could have this effect, the phenomenon of "blending." Sometimes a speaker will hesitate between two words or phrases, both reasonably appropriate for the situation in which he is speaking, and actually say something that is neither wholly one nor wholly the other, but a combination of parts of each. Hesitating between "Don't shout so loud" and "Don't yell so loud," he might come out with "Don't shell so loud." Blending is almost always involved in slips of the tongue, but it may



EVOLUTION OF LANGUAGE and some related characteristics are suggested by this classification of chordates. The lowest form of animal in each classification exhibits the features listed at the right of the class. Brackets indicate that each group possesses or has evolved beyond the characteristics exhibited by all the groups below. The 13 design-features of language appear in the colored rectangle. Some but by no means all of the characteristics associated with communication are presented in the column at right.

also be the regular mechanism by which a speaker of a language says something that he has not said before. Anything a speaker says must be either an exact repetition of an utterance he has heard before, or else some blended product of two or more such familiar utterances. Thus even such a smooth and normal sentence as "I tried to get there, but the car broke down" might be produced as a blend, say, of "I tried to get there but couldn't" and "While I was driving down Main Street the car broke down."

Children acquiring the language of their community pass through a stage that is closed in just the way gibbon calls are. A child may have a repertory of several dozen sentences, each of which, in adult terms, has an internal structure, and yet for the child each may be an indivisible whole. He may also learn new whole utterances from surrounding adults. The child takes the crucial step, however, when he first says something that he has not learned from others. The only way in which the child can possibly do this is by blending two of the whole utterances that he already knows.

In the case of the closed call-system of the gibbons or the protohominoids, there is no source for the addition of new unitary calls to the repertory except perhaps by occasional imitation of the calls and cries of other species. Even this would not render the system productive, but would merely enlarge it. But blending might occur. Let AB represent the food call and CD the danger call, each a fairly complex phonetic pattern. Suppose a protohominoid encountered food and caught sight of a predator at the same time. If the two stimuli were balanced just right, he might emit the calls ABCD or CDAB in quick sequence, or might even produce AD or CB. Any of these would be a blend. AD, for example, would mean "both food and danger." By

	A SOME GRYLLIDAE AND TETTIGONIIDAE	B BEE DANCING	C STICKLEBACK COURTSHIP	D WESTERN MEADOWLARK SONG
1 THE VOCAL-AUDITORY CHANNEL	AUDITORY, NOT VOCAL	NO	NO	YES
2 BROADCAST TRANSMISSION AND DIRECTIONAL RECEPTION	YES	YES	YES	YES
3 RAPID FADING (TRANSITORINESS)	YES, REPEATED	?	?	YES
4 INTERCHANGEABILITY	LIMITED	LIMITED	NO	?
5 TOTAL FEEDBACK	YES	?	NO	YES
6 SPECIALIZATION	YES?	?	IN PART	YES?
7 SEMANTICITY	NO?	YES	NO	IN PART ?
8 ARBITRARINESS	?	NO		IF SEMANTIC, YES
9 DISCRETENESS	YES?	NO	?	?
10 DISPLACEMENT		YES, ALWAYS		?
11 PRODUCTIVITY	NO	YES	NO	?
12 TRADITIONAL TRANSMISSION	NO?	PROBABLY NOT	NO?	?
13 DUALITY OF PATTERNING	? (TRIVIAL)	NO		?

EIGHT SYSTEMS OF COMMUNICATION possess in varying degrees the 13 design-features of language. Column A refers to members of the cricket family. Column H concerns only Western music since the time of Bach. A question mark means that it is virtue of this, AB and CD would acquire new meanings, respectively "food without danger" and "danger without food." And all three of these calls—AB, CD and AD—would now be composite rather than unitary, built out of smaller elements with their own individual meanings: A would mean "food"; B, "no danger"; C, "no food"; and D, "danger."

But this is only part of the story. The generation of a blend can have no effect unless it is understood. Human beings are so good at understanding blends that it is hard to tell a blend from a rote repetition, except in the case of slips of the tongue and some of the earliest and most tentative blends used by children. Such powers of understanding cannot be ascribed to man's prehuman ancestors. It must be supposed, therefore, that occasional blends occurred over many tens of thousands of years (perhaps, indeed, they still may occur from time to time among gibbons or the great apes), with rarely any appropriate communicative impact on hearers, before the understanding of blends became speedy enough to reinforce their production. However, once that did happen, the earlier closed system had become open and productive.

It is also possible to see how faint traces of displacement might develop in a call system even in the absence of productivity, duality and thoroughgoing traditional transmission. Suppose an early hominid, a man-ape say, caught sight of a predator without himself being seen. Suppose that for whatever reason—perhaps through fear—he sneaked silently back toward others of his band and only a bit later gave forth the danger call. This might give the whole band a better chance to escape the predator, thus bestowing at least slight survival value on whatever factor was responsible for the delay.

Something akin to communicative displacement is involved in lugging a stick or a stone around—it is like talking today about what one should do tomorrow. Of course it is not to be supposed that the first tool-carrying was purposeful, any more than that the first displaced communication was a discussion of plans. Caught in a *cul-de-sac* by a predator, however, the early hominid might strike out in terror with his stick or stone and by chance disable or drive off his enemy. In other words, the first tool-carrying had a consequence but not a purpose. Because the outcome was fortunate, it tended to reinforce whatever factor, genetic or traditional, prompted the behavior and made the outcome possible. In the end such events do lead to purposive behavior.

Although elements of displacement might arise in this fashion, on the whole it seems likely that some degree of productivity preceded any great proliferation of communicative displacement as well as any significant capacity for traditional transmission. A productive system requires the young to catch on to the ways in which whole signals are built out of smaller meaningful elements, some of which may never occur as whole signals in isolation. The young can do this only in the way that human children learn their language: by learning some utterances as whole units, in due time testing various blends based on that repertory, and finally adjusting their patterns of blending until the bulk of what they say matches what adults would say and is therefore understood. Part of this learning process is bound to take place away from the precise situations for which the responses are basically appropriate, and this means the promotion of displacement. Learning and teaching, moreover, call on any capacity for traditional transmission that the band may have. Insofar as the communicative system itself has survival value, all this bestows survival value also on the capacity

E GIBBON CALLS	F PARALINGUISTIC PHENOMENA	G LANGUAGE	H INSTRUMENTAL MUSIC
YES	YES	YES	AUDITORY, NOT VOCAL
YES	YES	YES	YES
YES, REPEATED	YES	YES	YES
YES	LARGELY YES	YES	?
YES	YES	YES	YES
YES	YES?	YES	YES
YES	YES?	YES	NO (IN GENERAL)
YES	IN PART	YES	
YES	LARGELY NO	YES	IN PART
NO	IN PART	YES, OFTEN	
NO	YES	YES	YES
?	YES	YES	YES
NO	NO	YES	

doubtful or not known if the system has the particular feature. A blank space indicates that feature cannot be determined because another feature is lacking or is indefinite.

for traditional transmission and for displacement. But these in turn increase the survival value of the communicative system. A child can be taught how to avoid certain dangers before he actually encounters them.

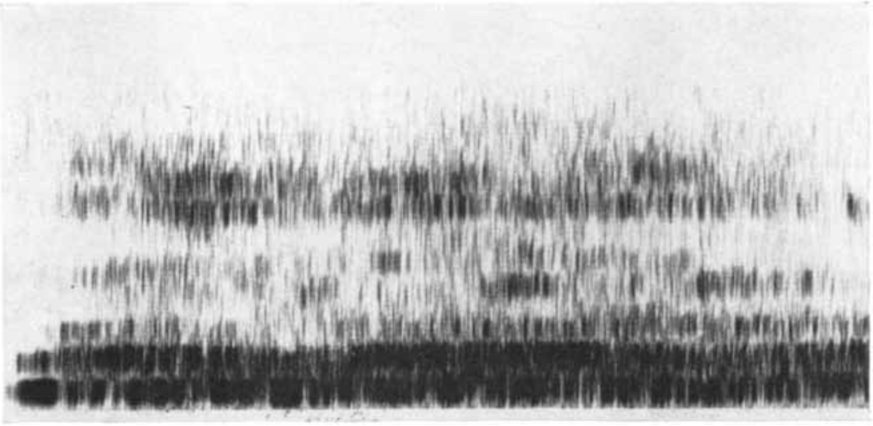
These developments are also necessarily related to the appearance of large and convoluted brains, which are better storage units for the conventions of a complex communicative system and for other traditionally transmitted skills and practices. Hence the adaptative value of the behavior serves to select genetically for the change in structure. A lengthened period of childhood helplessness is also a longer period of plasticity for learning. There is therefore selection for prolonged childhood and, with it, later maturity and longer life. With more for the young to learn, and with male as well as female tasks to be taught, fathers become more domesticated. The increase of displacement promotes retention and foresight; a male can protect his mate and guard her jealously from other males even when he does not at the moment hunger for her.

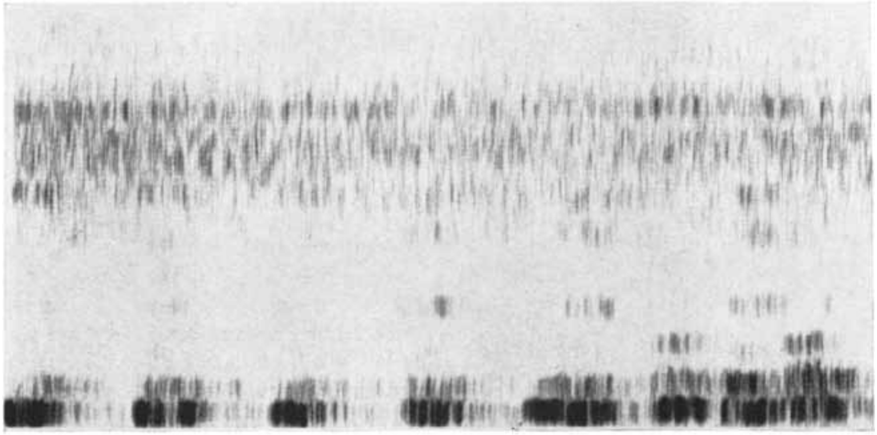
There is excellent reason to believe that duality of patterning was the last property to be developed, because one can find little if any reason why a communicative system should have this property unless it is highly complicated. If a vocal-auditory system comes to have a larger and larger number of distinct meaningful elements, those elements inevitably come to be more and more similar to one another in sound. There is a practical limit, for any species or any machine, to the number of distinct stimuli that can be discriminated, especially when the discriminations typically have to be made in noisy conditions. Suppose that Samuel F. B. Morse, in devising his telegraph code, had proposed a signal .1 second long for "A," .2 second long for "B," and so on up to 2.6 seconds for "Z." Operators would have enormous difficulty learning and using any such system. What Morse actually did was to incorporate the principle of duality of patterning. The telegraph operator has to learn to discriminate, in the first instance, only two lengths of pulse and about three lengths of pause. Each letter is coded into a different arrangement of these elementary meaningless units. The arrangements are easily kept apart because the few meaningless units are plainly distinguishable.

The analogy explains why it was advantageous for the forerunner of language, as it was becoming increasingly complex, to acquire duality of patterning. However it occurred, this was a major breakthrough; without it language could not possibly have achieved the efficiency and flexibility it has.

One of the basic principles of evolutionary theory holds that the initial survival value of any innovation is conservative in that it makes possible the maintenance of a largely traditional way of life in the face of changed circumstances. There was nothing in the makeup of the protohominoids that destined their descendants to become human. Some of them, indeed, did not. They made their way to ecological niches where food was plentiful and predators sufficiently avoidable, and where the development of primitive varieties of language and culture would have bestowed no advantage. They survive still, with various sorts of specialization, as the gibbons and the great apes.

Man's own remote ancestors, then, must have come to live in circumstances where a slightly more flexible system of communication, the incipient carrying and shaping of tools, and a slight increase in the capacity for traditional transmission made just the difference between surviving—largely, be it noted, by the good old protohominoid way of life—and dying out. There are various possibilities. If predators become more numerous and dangerous, any nonce use of a tool as a weapon, any co-operative mode of escape or attack might restore the balance. If food became scarcer, any technique for cracking harder nuts, for foraging over a wider territory, for sharing food so gathered or storing it when it was plentiful might promote survival of the band. Only after a very long period of such small adjustments to tiny changes of living conditions could the factors involved —incipient language, incipient tool-carrying and toolmaking, incipient culture— have started leading the way to a new pattern of life, of the kind called human.





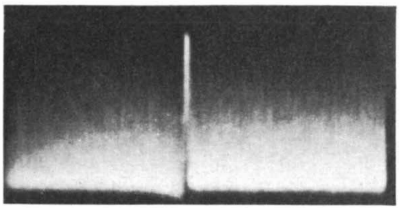
SUBHUMAN PRIMATE CALLS are represented here by sound spectrograms of the roar (*top*) and bark (*bottom*) of the howler monkey. Frequencies are shown vertically; time, horizontally. Roaring, the most prominent howler vocalization, regulates interactions and movements of groups of monkeys, and has both defensive and offensive functions. Barking has similar meanings but occurs when the monkeys are not quite so excited. Spectrograms were produced at Bell Telephone Laboratories from recordings made by Charles Southwick of the University of Southern Ohio during an expedition to Barro Colorado Island in the Canal Zone. The expedition was directed by C. R. Carpenter of Pennsylvania State University.

Kodak reports on:

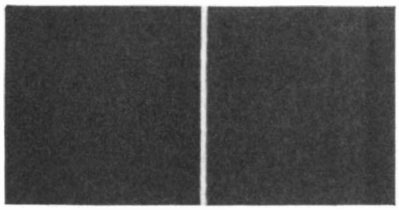
seeing the signal among the noise . . . a water-based lacquer . . . paste, beautiful paste

A human talent

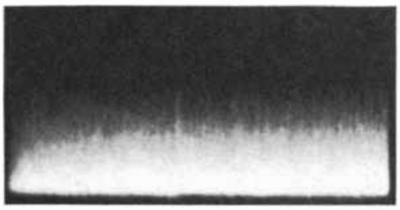
The June issue of this magazine contained an article full of learned speculation on the neurological mechanism by which lines, straight and curved, are perceived. Whatever the mechanism, the nervous system is very good at seeing a line from exceedingly faint physical stimuli. We had been thinking about ways this talent could help solve the nasty signal-to-noise problem that keeps cropping up on such occasions as when defense from submarine attack is considered. Today's almost instantly available photography makes a fine bridge from an electronic system to a human nervous system. For example:



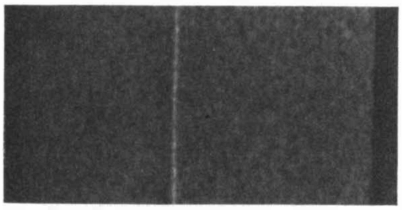
1. Instead of an ordinary A-scope trace like this . . .



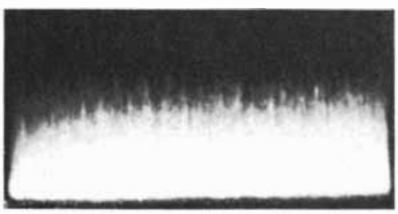
let's modulate intensity and sweep over moving film with much overlap . . .



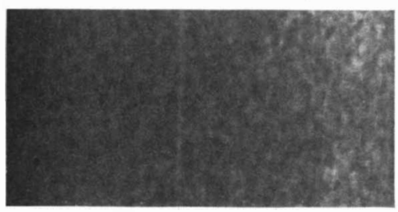
2. so that even when the significant pulse stands out from the noise no more than this . . .



photographic summing-up finds it rather easily;



3. and even when the A-scope shows only this . . .



the weak but non-random blip holds position and builds up from all the sweeps to where the marvelous combination of photography and the human perceptive mechanism says, "There!"

Organizations active in military developments who wish to know more about this work should communicate with Eastman Kodak Company, Apparatus and Optical Division, Rochester 4, N. Y.

Creamed butyrate

In this nation of do-it-yourselfers and of housewives capable of taking the bit in their own teeth when occasion demands, do you think there would be a market for a cream that can be spread over bare wood with cheesecloth to deposit in seconds a surface chemically and physically identical to a coat of highest quality lacquer?

We have made such a cream—a stable, freeze-and-thaw-resistant water emulsion of the same kind of cellulose acetate butyrate on which the best grades of conventional lacquers are based.

The cream eliminates separate fillers, sealers and wash coats, long drying periods, excessive sanding operations, and spraying equipment. With one, two, or three coats a range of effects can be produced from a flat "natural" surface to a rich, semi-glossy, "rubbed" surface. The fast film formation permits application of successive coats within minutes and eliminates the problem of surface imperfections from dust in the air. Gentle rubbing as the film forms fills the irregularities in the wood and smooths out the top of the lacquer. Though water-based, the cream does not raise grain. After drying, the film has good resistance to water. It adheres well to the wood, seals it well, prevents penetration of subsequently applied conventional finishes (if they are desired) but holds them tenaciously.

The product itself is almost water-white, with the color stability to sunlight for which all cellulose acetate butyrate coatings have been esteemed. It neither darkens wood nor is itself darkened with the passage of time.

All these interesting properties we have demonstrated to our own satisfaction. The intricacies of marketing such a product through paint stores, supermarkets, five-and-dimes, or similarly formidable retail channels fill us with dismay. Therefore we thought we would here ask around what companies are interested in trying to make hay with this lovely development. If indeed there are any such companies, Eastman Chemical Products Inc., Kingsport, Tenn. (Subsidiary of Eastman Kodak Company) will tell them all about emulsified butyrate.

Amylose and culture

Spaghetti and macaroni are basic.

The idea of making wheat flour up into a paste and drying it for future use must have come very early. Enter esthetics. The human spirit must be nourished along with the human body. For reasons apparently unrelated to biological metabolism, the paste must be dried in certain shapes, *and the integrity of these shapes must be preserved right to the pearly portal of the alimentary tract.* This principle is ancient: the ancient Romans ate spaghetti with cheese; the ancient Japanese ate macaroni pressed from a paste of cooked rice.

When spaghetti or macaroni is cooked for too long or allowed to stand cooked, the human spirit is offended. The morsels of *pasta* revert to a sticky paste, millenia of cultural advance undone because amylose has gone into solution and then has loosely hydrogen-bonded itself into a net of slime. But for this unfortunate tendency, the world's food supply would be less dependent on specialized durum wheats. Without them, the spaghetti and macaroni would get even stickier.

The problem now appears to be as soluble as the amylose itself.

First fruits of the victory can already be tasted. Try any of the up-to-date dehydrated potato-flake brands. Compare with home-whipped potato.

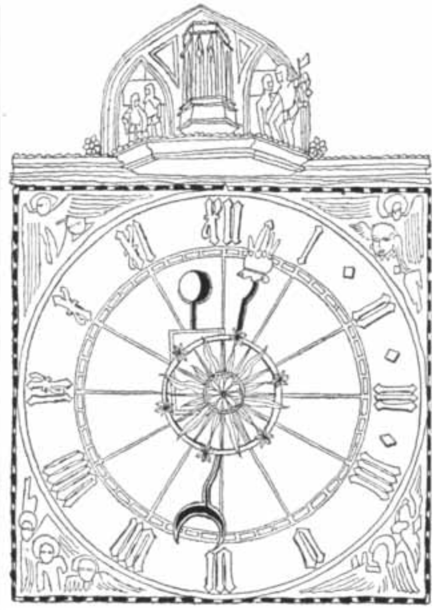
Whatever the future holds for spaghetti and macaroni, the reason the instant-potato thing works out so well is that the processors add a very small percentage of pure monoglyceride. It complexes the dissolved amylose so securely that even the familiar iodine-blue test can scarcely find it.

These Myverol Distilled Monoglycerides *we prepare by glycerolysis of familiar vegetable and animal food fats. They are officially recognized as safe. Investigators who would like samples of them with which to try remedying stickiness in any starchy foods are invited to write Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company).*

Kodak
TRADE MARK

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

SCIENCE AND



Scientists and Public Affairs

Scientists have been called on to take "an *independent* and *active* informative role" in helping the public arrive at decisions on matters related to science. The call came last month from the Committee on Science in the Promotion of Human Welfare of the American Association for the Advancement of Science. In a report published in the Association's journal *Science* the Committee warned that a growing "disparity between scientific progress and the resolution of the social issues which it has evoked . . . threatens to . . . disrupt the history of man."

As examples of matters on which adequate information is lacking the report mentioned radiation hazards, food additives and insecticides, the significance of space exploration, the nature of modern warfare, and the population question. Scientists were urged to acquaint themselves, as well as the public at large, with the technical aspects of such already pressing issues. In addition, they should "accept the obligation to determine how new [scientific] advances . . . are likely to affect human welfare, to call these matters to public attention, and to provide . . . objective statements of the facts and of the consequences of alternative policies."

Public ignorance, together with the growing importance of science as a military and political instrument, threatens to "erode" the integrity of science itself. Basic research "is poorly supported and, in the view of some observers, lacks vigor and quality." "The grim international competition for 'supremacy' in scientific accomplishment" may lead to "unseemly claims of priority." Secrecy arising out of military applications "may restrict the development of science. Some observers regard the problem of preventing the catastrophic application of the power of science in war as a matter which overshadows all others."

The Committee recommended that the A.A.A.S. should: (1) stimulate discussion of issues among scientists; (2) form special committees to prepare technical reports on issues of immediate interest; (3) translate the reports for lay readers and distribute them through all available channels; (4) encourage scientists to make themselves available as sources of information in their local communities.

Chairman of the Committee is Barry Commoner of Washington University in Saint Louis. The other members are Robert B. Brode of the University of California; Harrison Brown of the California Institute of Technology; T. C. Byerly of the Agricultural Research Service; Lawrence K. Frank of Belmont, Mass.; H. Jack Geiger of the Harvard Medical School; Frank W. Notestein of the Population Council; Margaret Mead of the American Museum of Natural History and Dael Wolfle of the A.A.A.S.

Forecasting by Satellite

As a result of the successful performance of the first weather satellite, *Tiros I,* cloud-cover data from satellites will be put to an early test as an aid to daily weather forecasting. When *Tiros II* is launched later this year, information gathered by its cameras will be speeded to weather stations over the U. S. Weather Bureau facsimile network.

Between April 1, when it was launched, and June 17, when the transmitter for its wide-angle camera failed, *Tiros I* sent back nearly 23,000 cloud pictures, more than 60 per cent of them usable. Cloud-cover diagrams constructed from the photographs proved surprisingly helpful in forecasting. Most of the "forecasts," however, were retrospective; no provision had been made for distributing the data quickly enough for "real time" predictions.

Several instances dramatically highlighted the potential value of satellite observations. On one occasion *Tiros* spotted extensive banks of heavy clouds in an area selected by the Air Force for an aerial refueling rendezvous, and could have prevented an unsuccessful mission if the information had been available in time. On another occasion the satellite found cloud conditions in the Caribbean that were inconsistent with a storm warning issued by the Weather Bureau; the storm forecast was canceled. On still another, by a stroke of good fortune, *Tiros* obtained what may be a clue to the development of tornadoes when it photographed a highly unusual square cloud formation that two hours later spawned a tornado.

Tiros II will have the same type of camera as *Tiros I*. Its cloud pictures are expected to be particularly useful in detecting storms originating over oceanic areas, from which surface weather observations are scant. In addition, the new satellite will carry instruments for the measurement of solar radiation entering the earth's atmosphere and of radiant energy reflected from the earth.

The Big Two

The huge alternating gradient synchrotron at Brookhaven National Laboratory has taken its first toddling giant step, accelerating a beam of protons to a record energy of 30 billion electron volts (Bev). It thus follows only a few months behind its cousin at CERN (European Council for Nuclear Research) near Geneva.

The two accelerators have the same fundamental design. Both hold protons on a circular path by means of an increasing magnetic field, as radiofrequency generators kick the particles to higher and higher energies. Both use strong focusing—an alternating sequence of focusing and defocusing magnetic fields with a net gathering-effect—to force the particles into a beam no more than a couple of inches across. The Brookhaven machine is slightly larger: Its track is 257 meters in diameter compared with 200 meters for the CERN synchrotron; its magnet weighs about 4,000 tons as against 3,200. When performing up to its specifications, it will produce a 32-Bev pulse, containing many billion protons, every three seconds. At CERN the accelerator is in regular operation at 25 Bev (and has gone up to 28) with a

100-billion-proton pulse, also on a cycle of three seconds. Before the CERN machine was completed, the most energetic accelerator was the 10-Bev "phasotron" in the U.S.S.R.

One key feature shared by the CERN and Brookhaven synchrotrons is a radically improved linear accelerator, which injects protons into the circular track at an energy of 50 million electron volts. This device also incorporates strong focusing, enabling it to deliver a much more intense beam than earlier versions can produce.

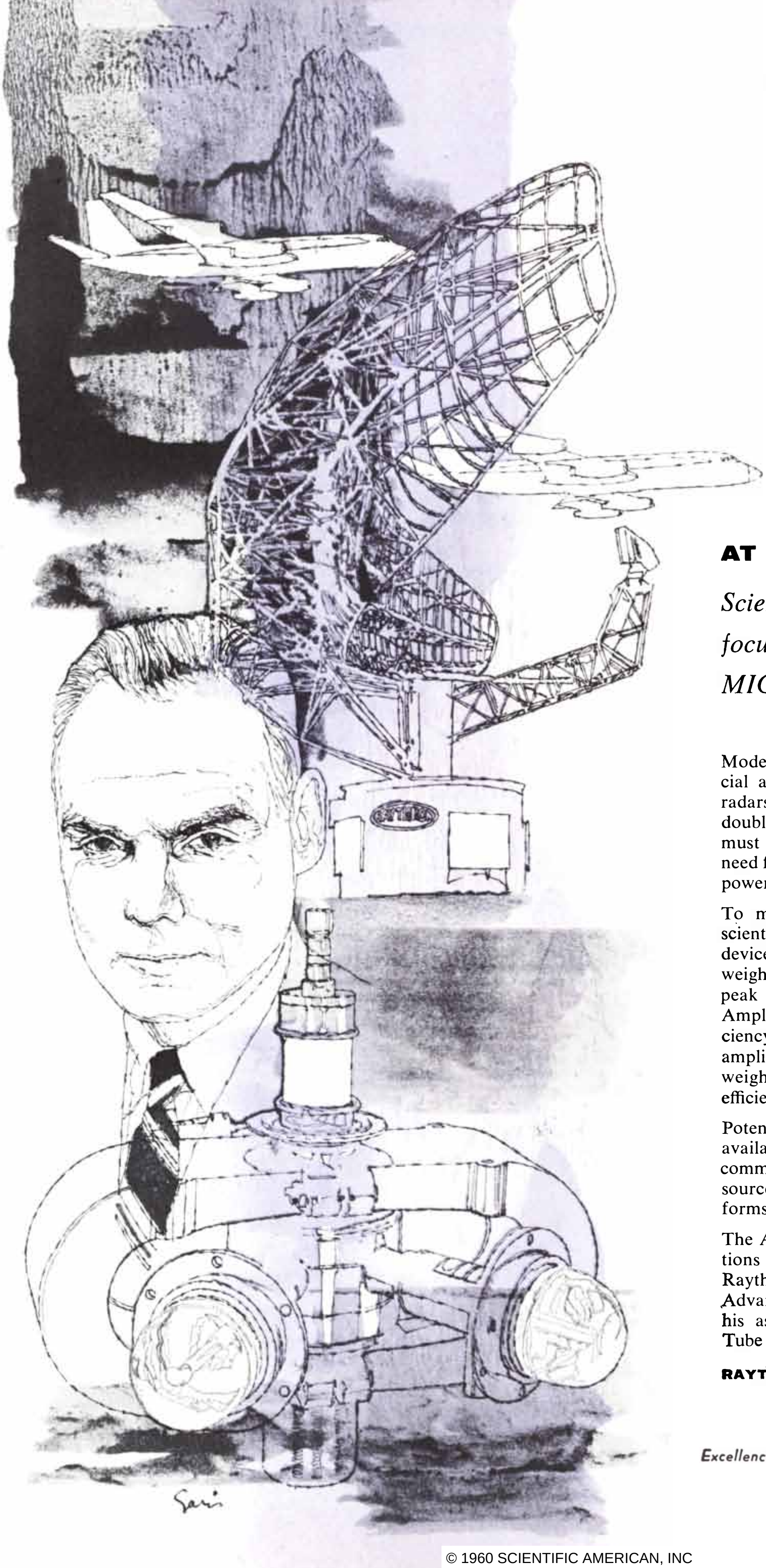
Although workers at Geneva are still adjusting and tuning up their synchrotron, they have already demonstrated that the big gamble represented by such machines ($31 million at Brookhaven) is going to pay off. No one knows as yet whether the accelerators will manufacture new fundamental particles. Until a few months ago it was not even clear that the known "strange" particles and their antiparticles would be manufactured in much greater quantity than they are by older machines.

This doubt has been resolved. While bringing the proton beam up to full strength, CERN physicists have been directing it against various targets and examining the resulting collision products. Strange particles such as K mesons and hyperons (particles heavier than protons) appear hundreds or thousands of times more frequently. Until now it has been a major undertaking to find them at all. Soon it will be possible to measure their rates of production. Antiprotons are made in such profusion that they themselves can be used as a beam to bombard other samples of matter. Also produced in surprisingly large quantity are deuterons: nuclei of heavy hydrogen containing a proton and a neutron.

It will be a few months before Brookhaven can begin to use its accelerator for experiments. If the same relations with CERN are then maintained as during the construction period, the two laboratories will work closely together. The Brookhaven workers emphasize that free interchange of ideas and personnel with CERN has contributed greatly to progress at both places.

Oldest Americans?

A six-inch bone fragment from the pelvis of a mastodon or mammoth, dug up recently in Mexico, may be proof that man was present in the New World 30,000 years ago. The fragment, inscribed with a number of drawings of animals, was found in an undisturbed Pleistocene deposit 60 miles from Mexi-



co City by Juan Armenta Camacho, head of the department of archeology at the University of Puebla.

In the same site were several other bone pieces bearing faint traces of what may have been engraving by man, and some 500 other bones that Armenta thinks were utensils. On geological grounds, and on the basis of the animal remains found in it, the deposit is estimated to be about 30,000 years old. If so, the fragment antedates by some 20,000 years the oldest man-made objects previously known in the New World: those left by Folsom man.

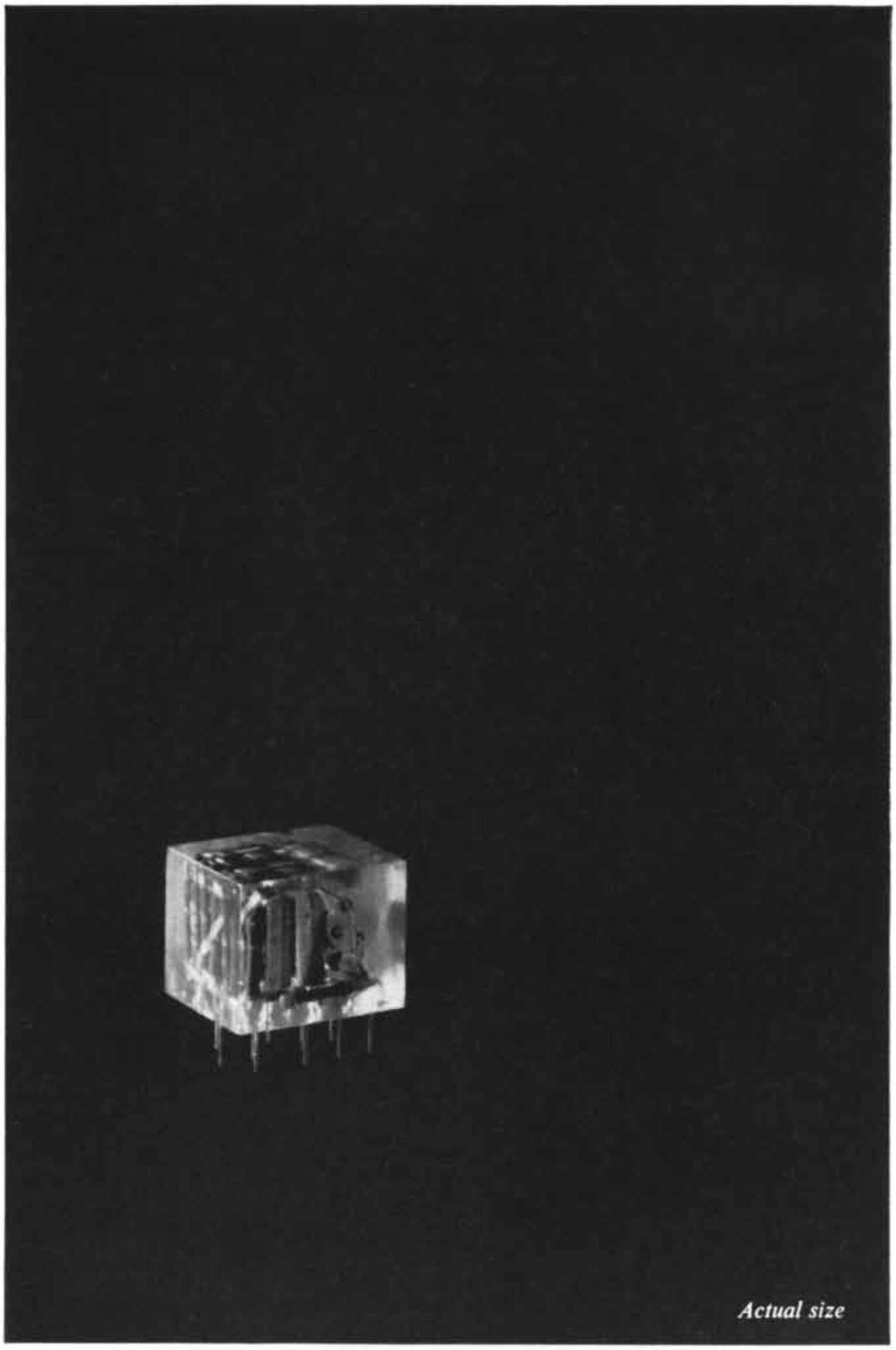
In the opinion of H. Marie Wormington of the Denver Museum of Natural History the drawings could not have been cut into the bone after it had fossilized, but must have been made while it was fresh. Samples of some of the excavated bones have been sent to the University of Michigan for radiocarbon dating. The radiocarbon method, however, is still subject to many uncertainties when applied to bone. According to some authorities on American archeology the best confirmation of the age of the drawings would be the discovery of similar bone engravings in other old, undisturbed deposits.

Cosmological Uncertainty

On the very largest scale, as on the smallest, man's efforts to discover the detailed workings of nature may be frustrated by an essential principle of uncertainty. So argues the British mathematician and cosmologist William H. McCrea in a recent issue of *Nature.*

He begins by assuming that every part of the universe interacts with every other, and that all interactions propagate at the speed of light. If so, the form in which we see distant parts of the universe is the form in which they are now exerting all their influence on our local region. "Therefore we can, in principle, predict the immediate future behavior of our own part of the universe."

The situation is quite different for regions remote from us and from each other. McCrea considers two regions, P and Q, each a billion light-years from the earth and in opposite directions. We see both P and Q as they were a billion years ago. But the influence that each was exerting on the other at that time depends on their respective states two billion years earlier, about which we have no information whatever. If the universe were finite, the difficulty could eventually be overcome by continuing observations for a sufficiently long time and then making predictions for still later times. However, "we almost cer-


Actual size

tainly have to regard the universe as unbounded. . . . It thus appears that there is an uncertainty in cosmology . . . occasioned by the fact that the speed of light is not infinite, that is complementary to the uncertainty in atomic physics . . . occasioned by the fact that the quantum of action is not zero."

McCrea has calculated that the differences between the predictions of "evolutionary" and "steady-state" cosmologies lie within the limits of this uncertainty. Therefore, he suggests, the question of which cosmology is correct is inherently unanswerable. In general, we can assert "almost nothing about what the universe is like at great distances (in space or time)." This view "seems more satisfactory than the recent trend toward a belief that the nature of the 'whole' universe has already been discovered."

Art Anticipates Nature

In 1953 a material apparently new under the sun was produced in a U. S. laboratory. Loring Coes, Jr., of the Norton Co., subjected silicon dioxide in the form of quartz to extremely high pressures and forced it into a superdense crystal that had never been seen before and that is now known as coesite. Since then mineralogists and geologists have been looking in vain for coesite in natural formations and in quartz-bearing rocks subjected to pressure from nuclear explosions. Last month a group from the U. S. Geological Survey found the stuff at last. It makes up as much as 20 per cent of the sandstone lining the floor of Meteor Crater, Ariz.

Edward C. T. Chao, Eugene M. Shoemaker and B. M. Madsen, who reported their discovery in *Science*, were able to isolate the material because it is relatively insoluble in hydrofluoric acid, which readily dissolves all the other components of the crater sandstone. The geologists say that the impact of the meteorite that made the crater must have produced pressures exceeding 300,000 pounds per square inch in order to have formed coesite. The mineral may afford a criterion for recognizing other impact craters on the earth, as well as on the moon and other planets.

Bomb Yields

In 169 nuclear tests the U. S. has exploded devices ranging in power from the equivalent of 15 million tons of TNT to 300 pounds. The figures were disclosed last month in a table listing the time, place and general character of the shock for virtually all U. S. test explo-

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BEGIN Ⓢ
R = 10 Ⓢ
F = 60 Ⓢ
L = ∘2 Ⓢ
FOR E = 100(50)300 BEGIN Ⓢ
FOR C = ∘00002(∘0000001)∘000021 BEGIN Ⓢ
I = E/SQRT(R ↑ 2 + (6∘2832 * F * L — (1/(6∘2832 * F * C))) ↑ 2) Ⓢ
PRINT (FL) = E Ⓢ
PRINT (FL) = C Ⓢ
PRINT (FL) = I Ⓢ
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sions, and the actual energy yield for 98. The table was prepared by Gerald W. Johnson of the Livermore Radiation Laboratory of the University of California, and is included in a memorandum issued by the Rand Corporation.

In the memorandum Frank Press of the California Institute of Technology and David Griggs of the University of California at Los Angeles urge seismologists to recheck their records using the precise data now available on the explosions. Such information is never obtainable for earthquakes.

The 71 shots whose yields were not released include many fired in the Pacific and two fired from rockets over the ocean. However, the table gives details not only on the 15-megaton shot, which was set off in the "Castle" series of 1954, but on a 14-megaton shot in 1952 that blasted away an island. The yield of the historic Alamogordo test on July 16, 1945, is also listed; it was 19,300 tons.

Monkey Malaria

Efforts to eradicate malaria have encountered a formidable new obstacle. It has been discovered that mosquitoes can transmit the disease from monkeys to man. Thus jungle animals are potential reservoirs of malarial infection, as in South and Central America they are a source of yellow fever that can be contained but not eliminated [see "Animal Infections and Human Diseases," by Meir Yoeli; SCIENTIFIC AMERICAN, May].

The discovery resulted from an accident in the Memphis laboratories of the National Institute of Allergy and Infectious Diseases, where two workers were bitten by Anopheles mosquitoes carrying a malaria parasite that infects monkeys. Two weeks later they developed the typical recurrent fever of tertian malaria. Subsequently a pair of volunteers who had allowed themselves to be bitten by mosquitoes fed on malarious monkeys also came down with the disease.

The world-wide campaign against malaria has been based on the assumption that it could be eliminated by clearing Anopheles mosquitoes from inhabited areas. Now it appears that they must be cleared from jungle areas as well—practically an impossible task. Thus the control of malaria may have to be a holding operation.

Tardy Tribute

Robert H. Goddard, the pioneer rocket researcher who died in 1945, has finally received recognition from the

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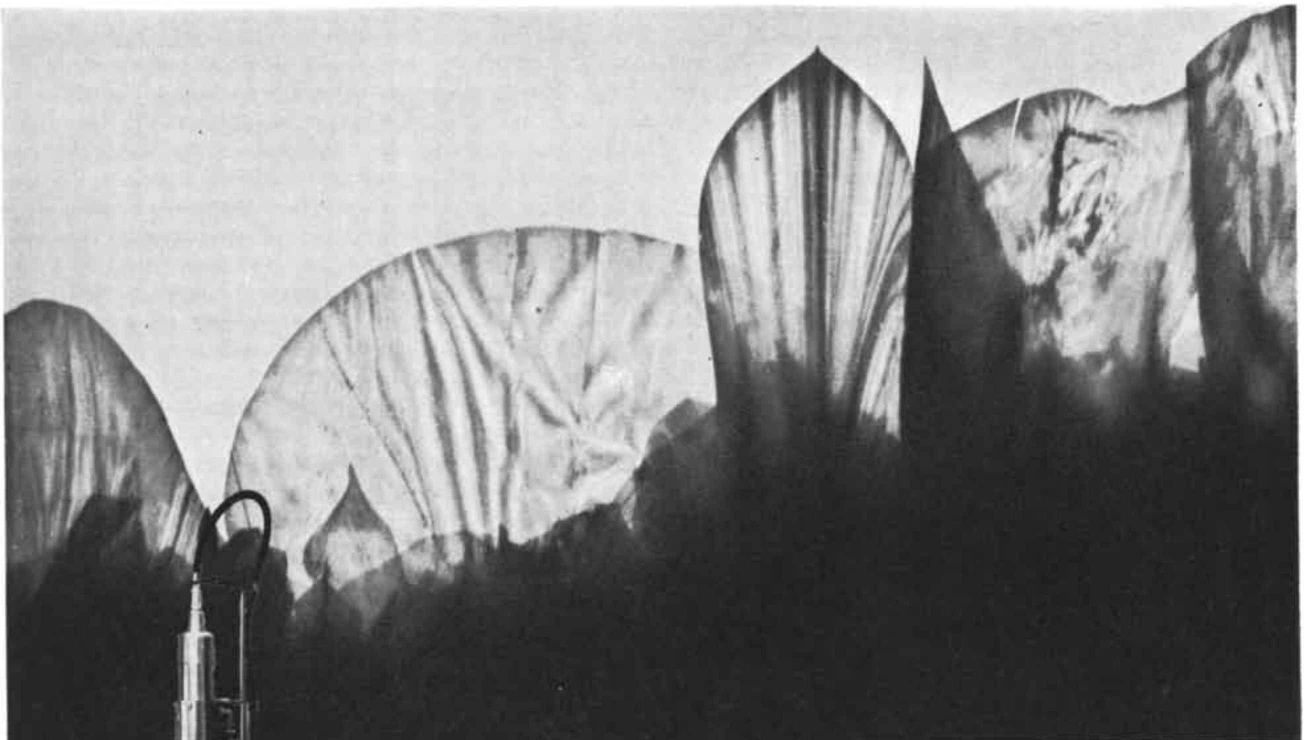

Crystal growths on stainless steel revealed by RCA Electron Microscope

Crystals which grow as billions of oxide "whiskers," or thin upright parallel plates, from the surface of stainless steel are revealed for the first time by the RCA Electron Microscope at the Westinghouse Research Laboratories, Pittsburgh. Their appearance may now explain destructive failure of the metal known as "stress corrosion cracking." Apparently, minute crevices grow downward into the metal surface as the crystals thrust themselves above it, causing a concentration of stress at the base of the crevice and eventually, failure. Studies such as these indicate the importance of the RCA Electron Microscope in the investigation of the fundamental mechanisms involved in corrosion.

The RCA Electron Microscope is proving invaluable throughout hundreds of laboratory applications. The EMU-3 provides electron image magnifications up to 200,000X. A convenient grouping of controls, and the automating of many functions contribute to the high efficiency of this instrument and provide unusual operating simplicity. These, plus a unique high-speed vacuum system, R-F power supply and exceptional stability are features that have made the RCA Electron Microscope the most widely used instrument of its kind.

Of special usefulness in chemical and metallurgical research is a new Diffraction Chamber, permitting these microscopes to perform reflection and transmission electron diffraction.

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In the above electron micrograph, oxide "whiskers" are seen to erupt from stainless steel after reaction with oxygen. By pre-stressing the steel and adding a trace of chloride ion in water vapor, the crystal habit changes and upright parallel plate crystals appear.

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U. S. Government for his contributions. Federal attorneys have concluded that the Government has infringed a substantial proportion of the numerous patents Goddard obtained during his lifetime. To expedite settlement of a claim filed in 1951 by Goddard's widow and the Daniel and Florence Guggenheim Foundation, which had supported much of Goddard's work and to which he had assigned his patents, the Government has conceded infringement of basic patents on liquid-fueled rockets. For this it will pay the Foundation $1 million, part of which will reimburse the Foundation for a prior settlement with Mrs. Goddard. In return the U. S. will receive paid-up licenses for more than 200 of Goddard's patents.

Goodbye to Pioneer V

At a distance of 22.5 million miles from the earth, and receding at 21,000 miles an hour, the little five-watt transmitter on *Pioneer V* peeped a final six-minute message to the radio telescope at Jodrell Bank in England, and then fell silent. The vehicle had maintained radio contact with the earth for almost three months after its launching on March 31. A 150-watt transmitter, which had been expected to keep it in communication out to 50 million miles, could not be used because of deterioration of the craft's solar batteries.

Despite a useful life less than half as long as had been hoped, *Pioneer V* produced a rich harvest of discoveries. Among the most striking were intense bursts of penetrating cosmic rays of solar origin, found well beyond the Van Allen radiation belts. Energetic streams of both protons and electrons from the sun were also detected; the electrons were encountered by the satellite not only during solar flares (which are known to eject energetic electrons) but at other times as well.

Magnetometer readings traced the terrestrial magnetic field out to 64,000 miles from the earth—twice as far as the field was supposed to extend. Beyond that distance *Pioneer V* detected an interplanetary magnetic field perpendicular to the earth's orbit. The intensity of the field is about 2.5 gamma, roughly a twenty thousandth of the strength of the field at the surface of the earth. Moreover, the far-flying vehicle encountered a region of magnetic turbulence where the "wind" of protons streaming from the sun strikes the earth's magnetic field, and a "ring current" of low-energy protons and electrons circling the earth at a distance of 40,000 miles.

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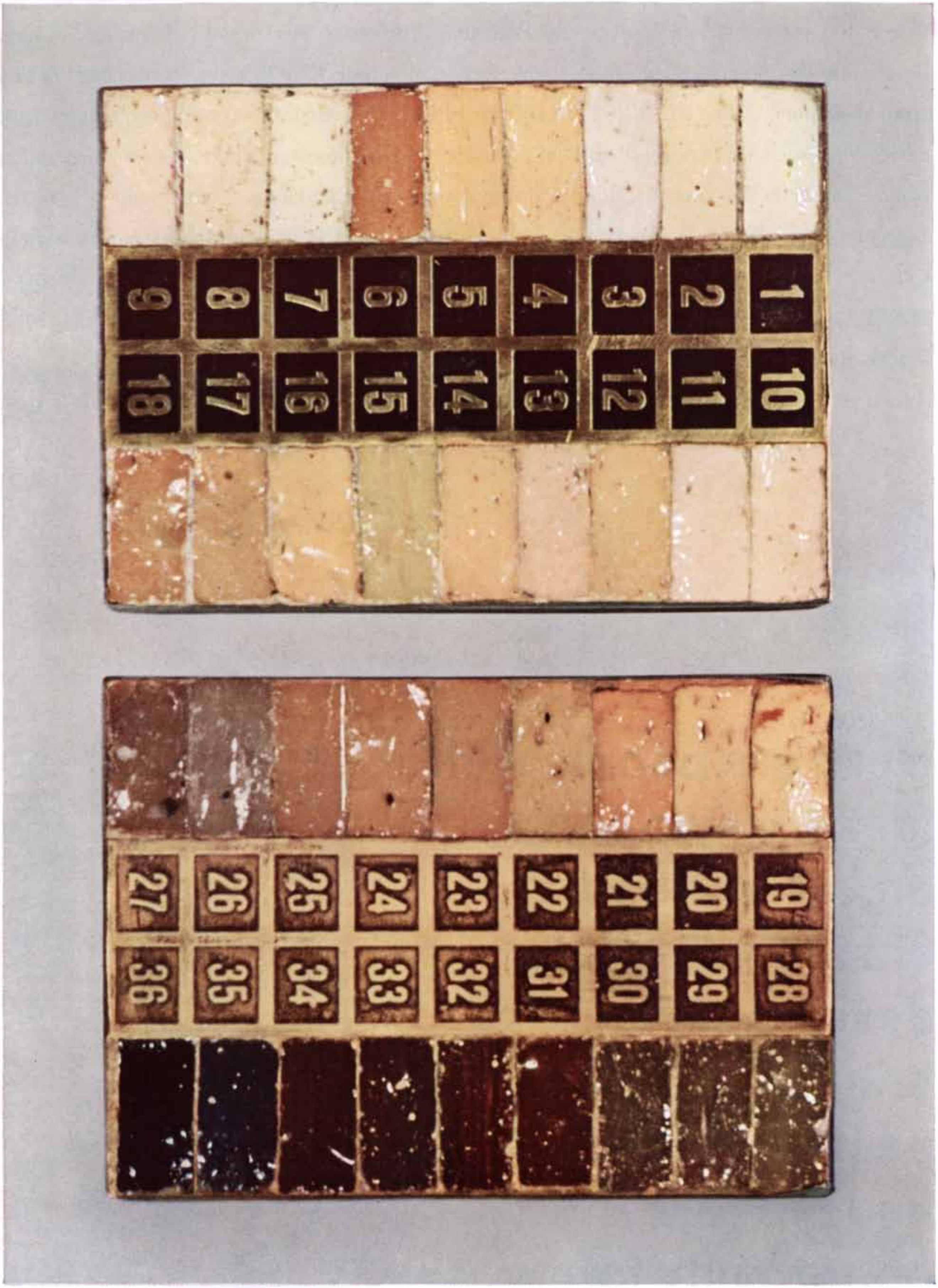


COLOR OF HUMAN SKIN is sometimes measured by physical anthropologists on the von Luschan scale. Reproduced here somewhat larger than natural size, the scale consists of numbered ceramic tiles which are compared visually to color of the underside of subject's forearm. Both sides of the scale are shown; colors range from almost pure white (*top right*) to black (*bottom left*).

The Distribution of Man

Homo sapiens arose in the Old World, but has since become the most widely distributed of all animal species. In the process he has differentiated into three principal strains

by William W. Howells

Men with chins, relatively small brow ridges and small facial skeletons, and with high, flat-sided skulls, probably appeared on earth in the period between the last two great continental glaciers, say from 150,000 to 50,000 years ago. If the time of their origin is blurred, the place is no less so. The new species doubtless emerged from a number of related populations distributed over a considerable part of the Old World. Thus *Homo sapiens* evolved as a species and began to differentiate into races at the same time.

In any case, our direct ancestor, like his older relatives, was at once product and master of the crude pebble tools that primitive human forms had learned to use hundreds of thousands of years earlier. His inheritance also included a social organization and some level of verbal communication.

Between these hazy beginnings and the agricultural revolution of about 10,000 years ago *Homo sapiens* radiated over most of the earth, and differentiated into clearly distinguishable races. The processes were intimately related. Like the forces that had created man, they reflected both the workings of man's environment and of his own invention. So much can be said with reasonable confidence. The details are another matter. The when, where and how of the origin of races puzzle us not much less than they puzzled Charles Darwin.

A little over a century ago a pleasingly simple explanation of races enjoyed some popularity. The races were separate species, created by God as they are today. The Biblical account of Adam and Eve was meant to apply only to Caucasians. Heretical as the idea might be, it was argued that the Negroes appearing in Egyptian monuments, and the skulls of the ancient Indian mound-builders of Ohio, differed in no way from their living descendants, and so there could have been no important change in the only slightly longer time since the Creation itself, set by Archbishop Ussher at 4004 B.C.

With his *Origin of Species,* Darwin undid all this careful "science" at a stroke. Natural selection and the immense stretch of time provided by the geological time-scale made gradual evolution seem the obvious explanation of racial or species differences. But in his later book, *The Descent of Man,* Darwin turned his back on his own central notion of natural selection as the cause of races. He there preferred sexual selection, or the accentuation of racial features through long-established ideals of beauty in different segments of mankind. This proposition failed to impress anthropologists, and so Darwin's demolishing of the old views left something of a void that has never been satisfactorily filled.

Not for want of trying. Some students continued, until recent years, to insist that races are indeed separate species, or even separate genera, with Whites descended from chimpanzees, Negroes from gorillas and Mongoloids from orangutans. Darwin himself had already argued against such a possibility when a contemporary proposed that these same apes had in turn descended from three different monkey species. Darwin pointed out that so great a degree of convergence in evolution, producing thoroughgoing identities in detail (as opposed to, say, the superficial resemblance of whales and fishes) simply could not be expected. The same objection applies to a milder hypothesis, formulated by the late Franz Weidenreich during the 1940's. Races, he held, descended separately, not from such extremely divergent parents as the several great apes, but from the less-separated lines of fossil men. For example, Peking man led to the Mongoloids, and Rhodesian man to the "Africans." But again there are more marked distinctions between those fossil men than between living races.

Actually the most reasonable—I should say the only reasonable—pattern suggested by animal evolution in general is that of racial divergence within a stock already possessing distinctive features of *Homo sapiens.* As I have indicated, such a stock had appeared at the latest by the beginning of the last glacial advance and almost certainly much earlier, perhaps by the end of the preceding glaciation, which is dated at some 150,000 years ago.

Even if fossil remains were more plentiful than they are, they might not in themselves decide the questions of time and place much more accurately. By the time *Homo sapiens* was common enough to provide a chance of our finding some of his fossil remains, he was probably already sufficiently widespread as to give only a general idea of his "place of origin." Moreover, bones and artifacts may concentrate in misleading places. (Consider the parallel case of the australopithecine "man-apes" known so well from the Lower Pleistocene of South Africa. This area is thought of as their home. In fact the region actually was a geographical *cul-de-sac,* and merely a good fossil trap at that time. It is now clear that such prehumans were widespread not only in Africa but also in Asia. We have no real idea of their first center of dispersion, and we should assume that our earliest knowledge of them is not from the actual dawn of their existence.)

In attempting to fix the emergence

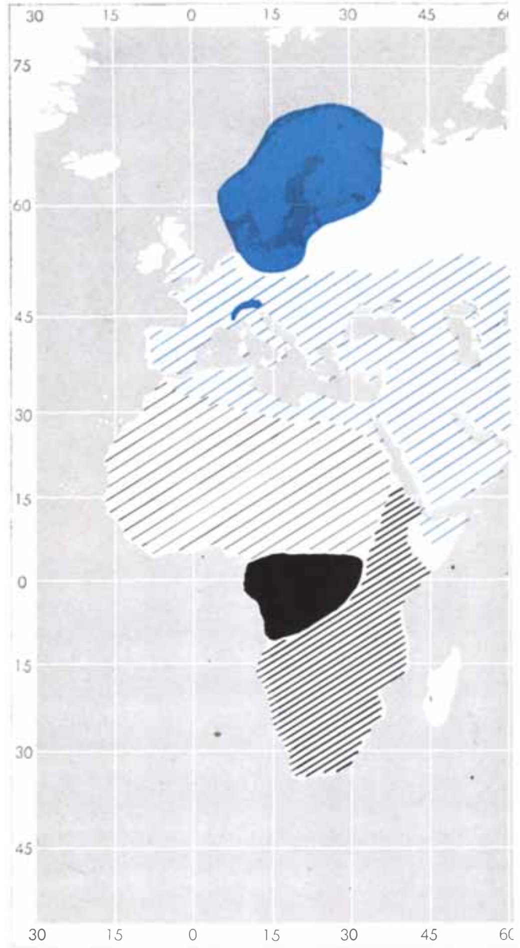
of modern races of man somewhat more precisely we can apply something like the chronological reasoning of the pre-Darwinians. The Upper Paleolithic invaders of Europe (*e.g.*, the Cro-Magnons) mark the definite entrance of *Homo sapiens*, and these men were already stamped with a "White" racial nature at about 35,000 B.C. But a recently discovered skull from Liukiang in China, probably of the same order of age, is definitely not Caucasian, whatever else it may be. And the earliest American fossil men, perhaps 20,000 years old, are recognizable as Indians. No other remains are certainly so old; we cannot now say anything about the first Negroes. Thus racial differences are definitely older than 35,000 years. And yet—this is sheer guess—the more successful *Homo sapiens* would probably have overcome the other human types, such as Neanderthal and Rhodesian men, much earlier if he had reached his full development long before. But these types survived well into the last 50,000 years. So we might assume that *Homo sapiens*, and his earliest racial distinctions, is a product of the period between the last two glaciations, coming into his own early during the last glaciation.

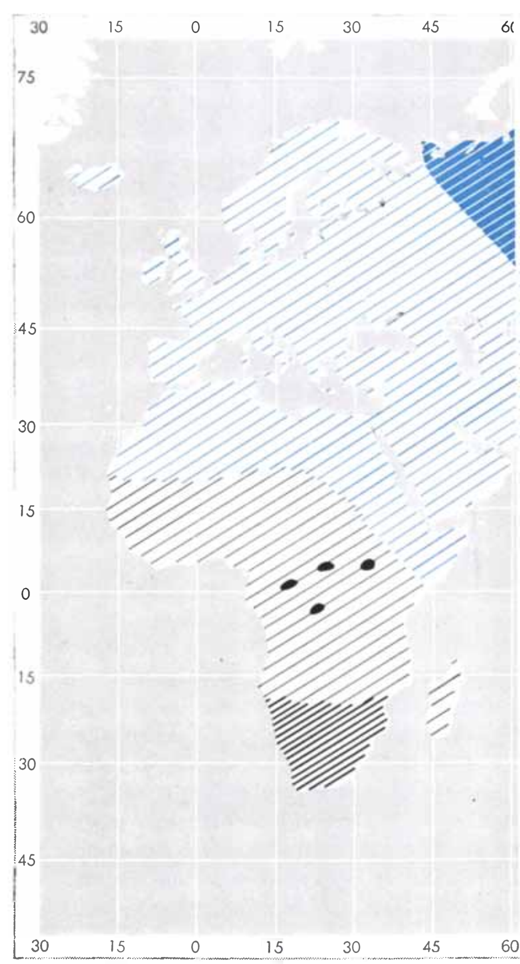
When we try to envisage the causes of racial development, we think today of four factors: natural selection, genetic drift, mutation and mixture (interbreeding). With regard to basic divergence at the level of races, the first two are undoubtedly the chief determinants. If forces of any kind favor individuals of one genetic complexion over others, in the sense that they live and reproduce more successfully, the favored individuals will necessarily increase their bequest of genes to the next generation relative to the rest of the population. That is selection; a force with direction.

Genetic drift is a force without direction, an accidental change in the gene proportions of a population. Other things being equal, some parents just have more offspring than others. If such variations can build up, an originally homogeneous population may split into two different ones by chance. It is somewhat as though there were a sack containing 50 red and 50 white billiard balls, each periodically reproducing itself, say by doubling. Suppose you start a new population, drawing out 50 balls without looking. The most likely single result would be 25 of each color, but it is more likely that you would end up with some other combination, perhaps as extreme as 20 reds and 30 whites. After this population divides, you make a new drawing, and so on. Of course at each subsequent step the departure from the then-prevailing proportion is as likely to favor red as white. Nevertheless, once the first drawing has been made with the above result, red has the better chance of vanishing. So it is with genes for hereditary traits.

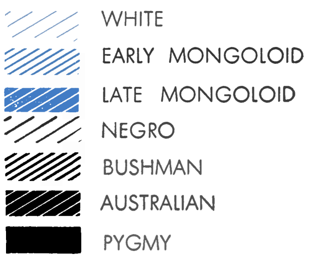
Both drift and selection should have stronger effects the smaller and more isolated the population. It is easy to imagine them in action among bands of ancient men, living close to nature. (It would be a great mistake, however, to imagine that selection is not also effective in modern populations.) Hence we can look upon racial beginnings as part accident, part design, design meaning any pattern of minor change obedient to natural selection.

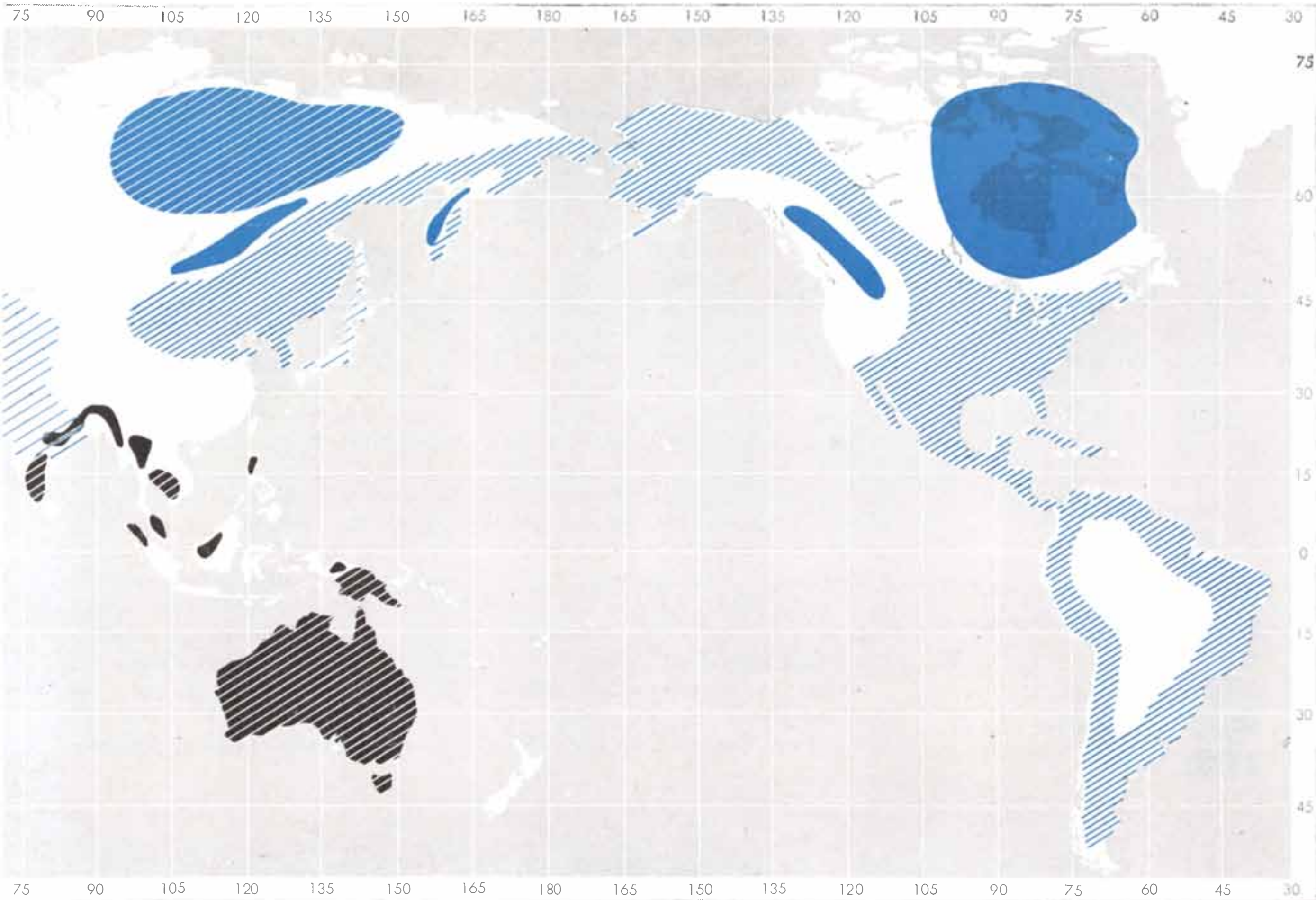
Darwin was probably right the first time, then, and natural selection is more important in racial adaptation than he himself later came to think. Curiously, however, it is extremely difficult to find demonstrable, or even logically appealing, adaptive advantages in racial features. The two leading examples of adaptation in human physique are not usually considered racial at all. One is the tendency among warm-blooded animals of the same species to be larger in colder parts of their territory. As an animal of a given shape gets larger, its inner bulk increases faster than its outer surface,





DISTRIBUTION OF MAN and his races in three epochs is depicted in the maps on these and the following two pages. Key to the races appears in legend below. Solid blue areas in map at top represent glaciers. According to available evidence, it is believed that by 8000 B.C. (*map at top*) early Mongoloids had already spread from the Old World to the New World, while late Mongoloids inhabited a large part of northern Asia. Distribution in A.D. 1000 (*map at bottom*) has late Mongoloids dominating Asia, northern Canada and southern Greenland, and early Mongoloids dominating the Americas. The Pygmies and Bushmen of Africa began a decline that has continued up to the present (*see map on next two pages*).

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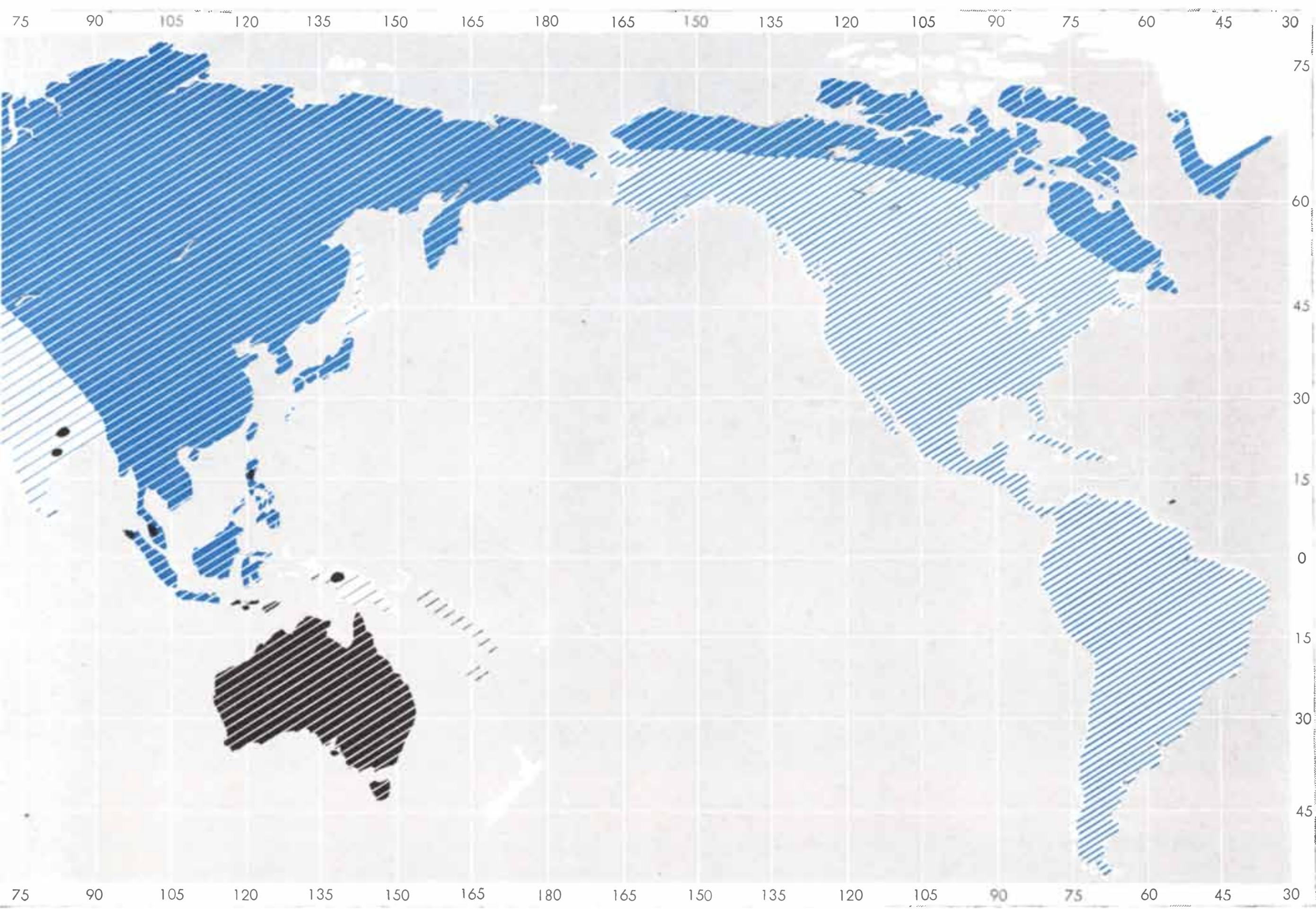
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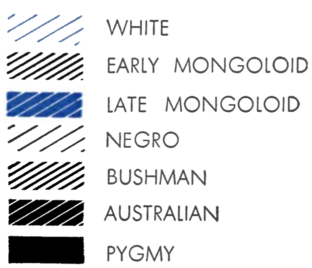
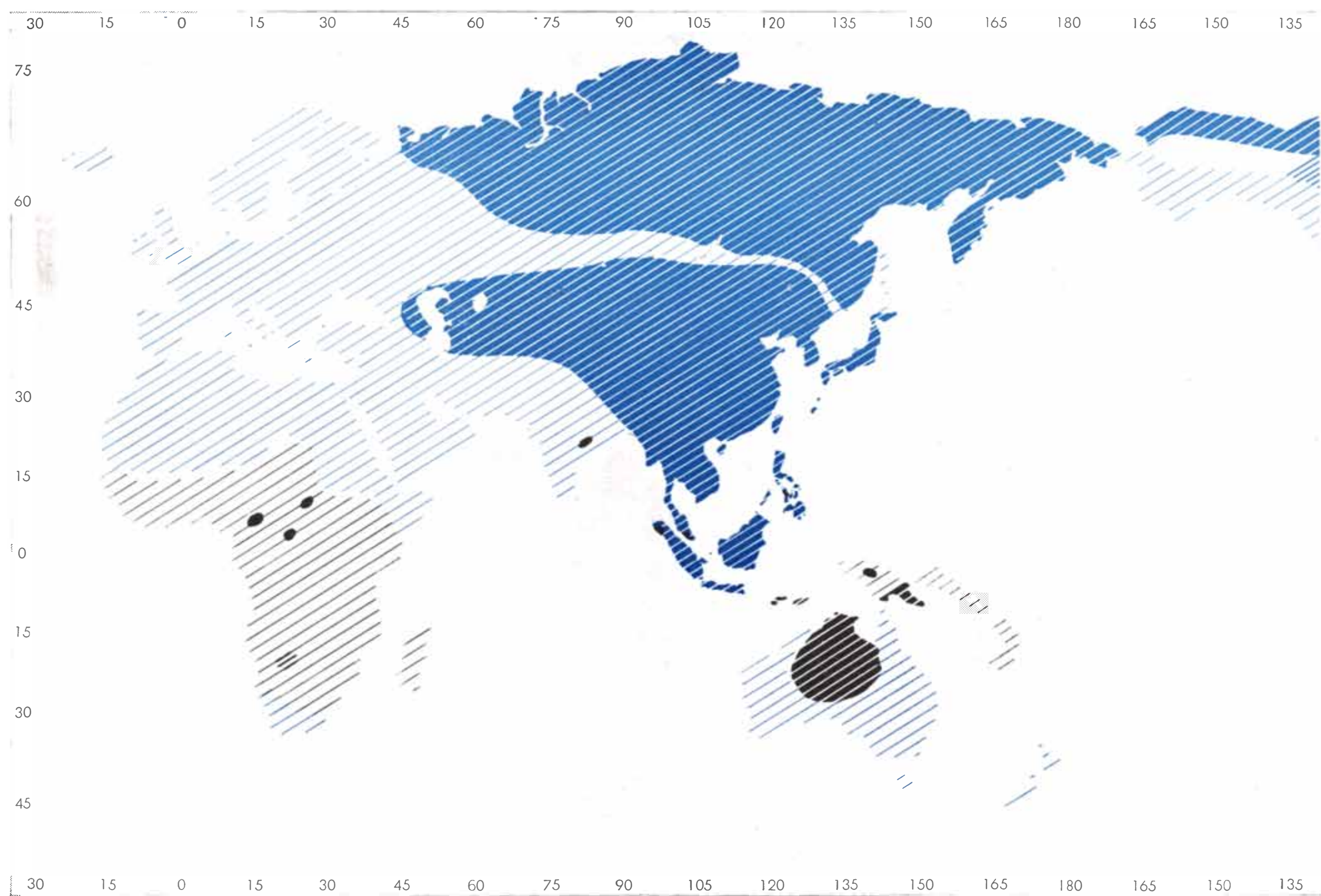
so the ratio of heat produced to heat dissipated is higher in larger individuals. It has, indeed, been shown that the average body weight of man goes up as annual mean temperature goes down, speaking very broadly, and considering those populations that have remained where they are a long time. The second example concerns the size of extremities (limbs, ears, muzzles). They are smaller in colder parts of the range and larger in warmer, for the same basic reason—heat conservation and dissipation. Man obeys this rule also, producing lanky, long-limbed populations in hot deserts and dumpy, short-limbed peoples in the Arctic.

This does not carry us far with the major, historic races as we know them. Perhaps the most striking of all racial features is the dark skin of Negroes. The color of Negro skin is due to a concentration of melanin, the universal human pigment that diffuses sunlight and screens out its damaging ultraviolet component. Does it not seem obvious that in the long course of time the Negroes, living astride the Equator in Africa and in the western Pacific, developed their dark skins as a direct response to a strong sun? It makes sense. It would be folly to deny that such an adaptation is present. But a great deal of the present Negro habitat is shade forest and not bright sun, which is in fact strongest in the deserts some distance north of the Equator. The Pygmies are decidedly forest dwellers, not only in Africa but in their several habitats in southeastern Asia as well.

At any rate there is enough doubt to have called forth other suggestions. One is that forest hunters needed protective coloration, both for stalking and for their protection from predators; dark skin would have lowest visibility in the patchy light and shade beneath the trees. Another is that densely pigmented skins may have other qualities—*e.g.*, resistance to infection—of which we are unaware.

A more straightforward way out of the dilemma is to suppose that the Negroes are actually new to the Congo forest, and that they served their racial apprenticeship hunting and fishing in the sunny grasslands of the southern Sahara. If so, their Pygmy relatives might represent the first accommodation of the race to the forest, before agriculture but after dark skin had been acquired. Smaller size certainly makes a chase after game through the undergrowth less exhausting and faster. As for woolly hair, it is easy to see it (still without proof) as an excellent, nonmatting insulation against solar heat. Thick Negro lips? Every suggestion yet made has a zany sound. They may only be a side effect of some properties of heavily pigmented



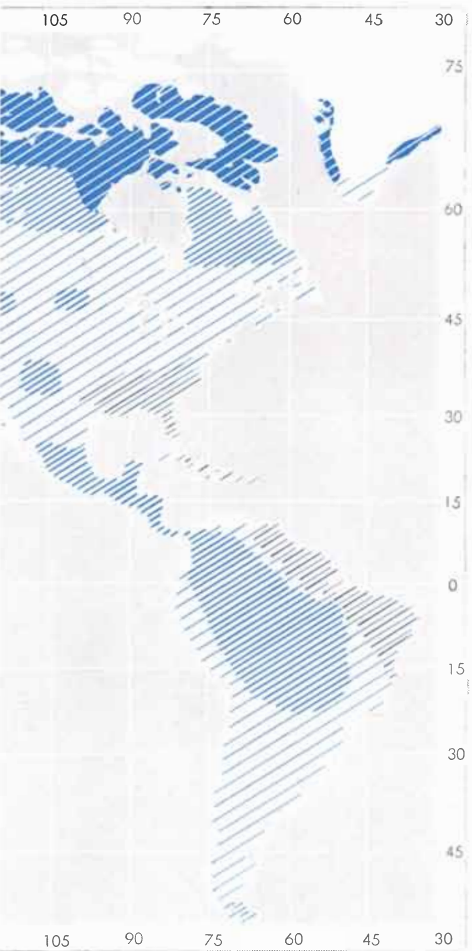


PRESENT DISTRIBUTION OF RACES OF MAN reflects dominance of White, late Mongoloid and Negro races. Diffusion of Whites has been attended by decline of early Mongoloids in America, Bushmen in Africa and indigenous population in Australia.

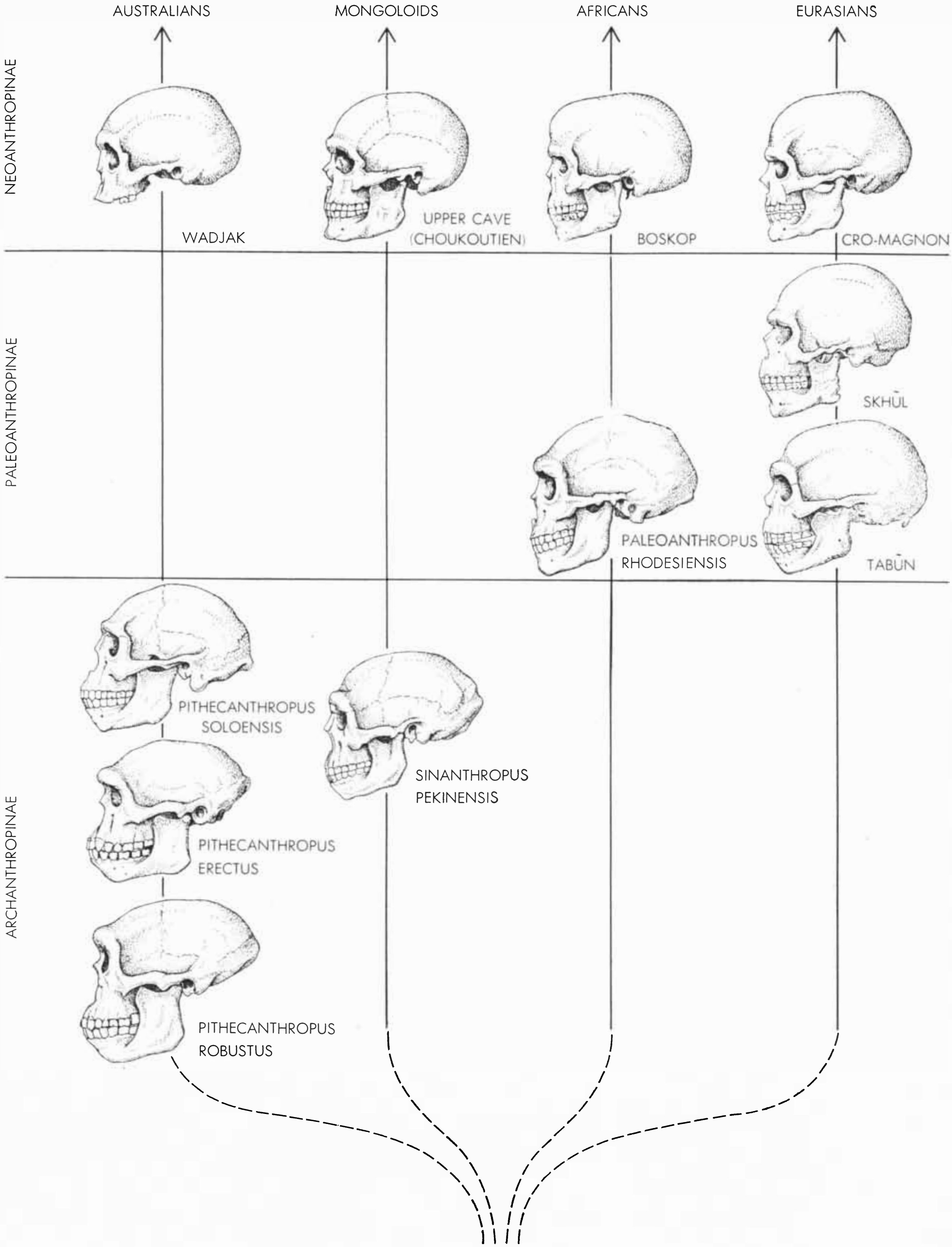
skin (ability to produce thick scar tissue, for example), even as blond hair is doubtless a side effect of the general depigmentation of men that has occurred in northern Europe.

At some remove racially from Negroes and Pygmies are the Bushmen and Hottentots of southern Africa. They are small, or at least lightly built, with distinctive wide, small, flat faces; they are rather infantile looking, and have a five-cornered skull outline that seems to be an ancient inheritance. Their skin is yellowish-brown, not dark. None of this has been clearly interpreted, although the small size is thought to be an accommodation to water and food economy in the arid environment. The light skin, in an open sunny country, contradicts the sun-pigment theory, and has in fact been used in favor of the protective-coloration hypothesis. Bushmen and background blend beautifully for color, at least as human beings see color.

Bushmen, and especially Hottentots, have another dramatic characteristic:



Narrow band of Whites in Asia represents Russian colonization of southern Siberia.



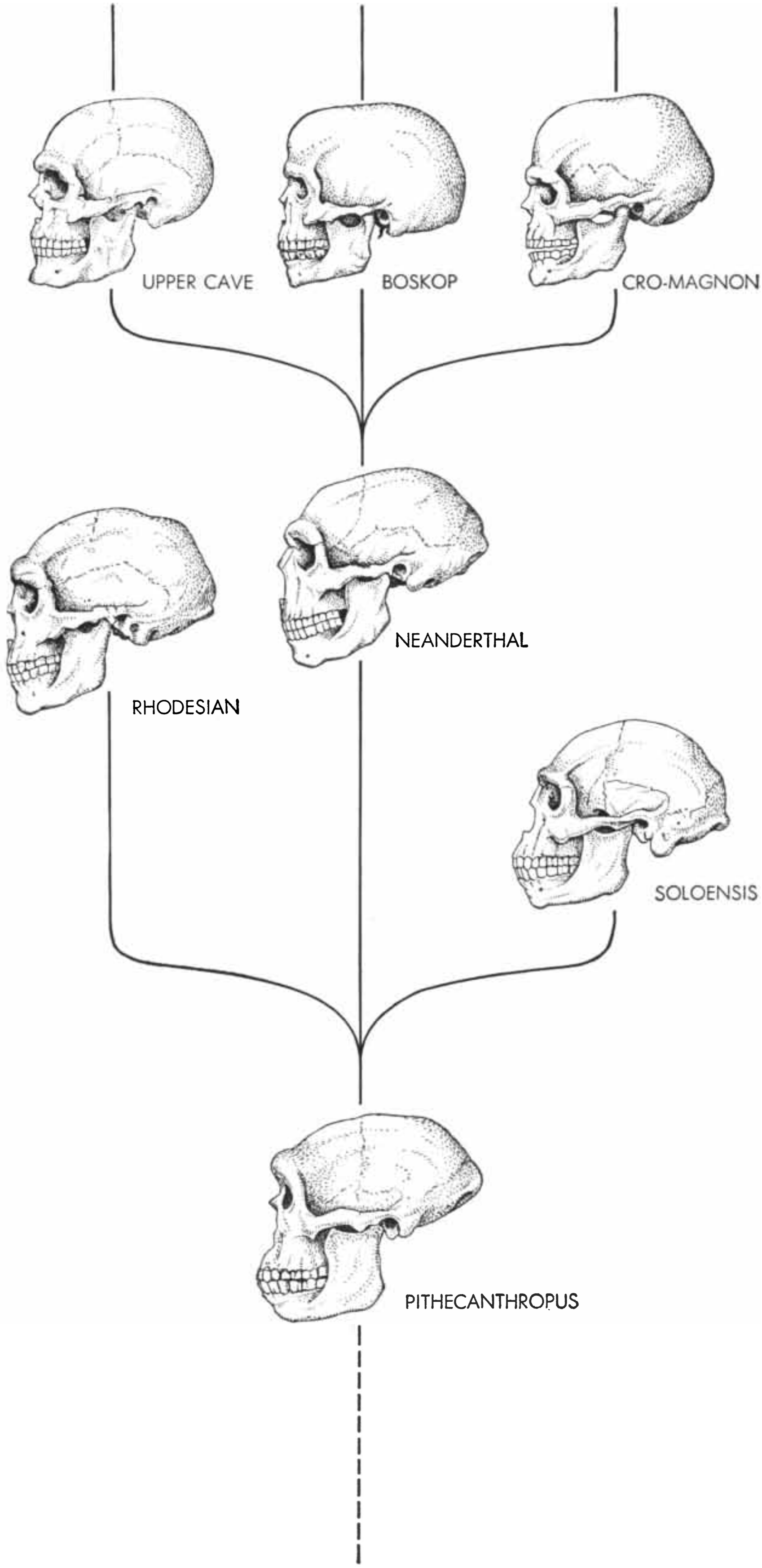
POLYPHYLETIC SCHOOL of anthropology, chiefly identified with Franz Weidenreich, conceives modern races of man descending from four ancestral lines. According to this school, ancestors of Australians (*left*) include *Pithecanthropus soloensis* (Solo man) and *Pithecanthropus erectus* (Java man). Original ancestor of Mongoloids is *Sinanthropus pekinensis* (Peking man); of Africans, *Paleoanthropus rhodesiensis* (Rhodesian man). Four skulls at top are early *Homo sapiens*. Alternative theory is shown on page 120.

steatopygia. If they are well nourished, the adult women accumulate a surprising quantity of fat on their buttocks. This seems to be a simple storehouse mechanism reminiscent of the camel's hump; a storehouse that is not distributed like a blanket over the torso generally, where it would be disadvantageous in a hot climate. The characteristic nicely demonstrates adaptive selection working in a human racial population.

The Caucasians make the best argument for skin color as an ultraviolet screen. They extend from cloudy northern Europe, where the ultraviolet in the little available sunlight is not only acceptable but desirable, down to the fiercely sun-baked Sahara and peninsular India. All the way, the correspondence with skin color is good: blond around the Baltic, swarthy on the Mediterranean, brunet in Africa and Arabia, dark brown in India. Thus, given a long enough time of occupation, and doubtless some mixture to provide dark-skinned genes in the south, natural selection could well be held responsible.

On the other hand, the Caucasians' straight faces and often prominent noses lack any evident adaptive significance. It is the reverse with the Mongoloids, whose countenances form a coherent pattern that seems consistent with their racial history. From the standpoint of evolution it is Western man, not the Oriental, who is inscrutable. The "almond" eyes of the Mongoloid are deeply set in protective fat-lined lids, the nose and forehead are flattish and the cheeks are broad and fat-padded. In every way, it has been pointed out, this is an ideal mask to protect eyes, nose and sinuses against bitterly cold weather. Such a face is the pole toward which the peoples of eastern Asia point, and it reaches its most marked and uniform expression in the cold northeastern part of the continent, from Korea north.

Theoretically the Mongoloid face developed under intense natural selection some time during the last glacial advance among peoples trapped north of a ring of mountain glaciers and subjected to fierce cold, which would have weeded out the less adapted, in the most classic Darwinian fashion, through pneumonia and sinus infections. If the picture is accurate, this face type is the latest major human adaptation. It could not be very old. For one thing, the population would have had to reach a stage of advanced skill in hunting and living to survive at all in such cold, a stage probably not attained before the Upper Paleolithic (beginning about 35,000 B.C.). For an-



UNILINEAR OR "HAT-RACK" SCHOOL predicates three races descending from single ancestral line, as opposed to polyphyletic theory depicted on page 118. Rhodesian, Neanderthal and Solo man all descend from *Pithecanthropus*. Neanderthal is ancestor of early *Homo sapiens* (Upper Cave, Boskop and Cro-Magnon) from which modern races descended.

after the American Indians, who are Mongoloid but without the transformed face, migrated across the Bering Strait. (Only the Eskimos reflect the extension of full-fledged, recent Mongoloids into America.) All this suggests a process taking a relatively small number of generations (about 600) between 25,000 and 10,000 B. C.

The discussion so far has treated human beings as though they were any mammal under the influence of natural selection and the other forces of evolution. It says very little about why man invaded the various environments that have shaped him and how he got himself distributed in the way we find him now. For an understanding of these processes we must take into account man's own peculiar abilities. He has created culture, a milieu for action and development that must be added to the simplicities of sun, snow, forest or plain.

Let us go back to the beginning. Man started as an apelike creature, certainly vegetarian, certainly connected with wooded zones, limited like all other primates to tropical or near-tropical regions. In becoming a walker he had begun to extend his range. Tools, social rules and intelligence all progressed together; he learned to form efficient groups, armed with weapons not provided by nature. He started to eat meat, and later to cook it; the more concentrated diet widened his possibilities for using his time; the hunting of animals beckoned him still farther in various directions.

All this was probably accomplished during the small-brained australopithecine stage. It put man on a new plane, with the potential to reach all parts of the earth, and not only those in which he could find food ready to his hand, or be comfortable in his bare skin. He did not actually reach his limits until the end of the last glaciation, and in fact left large tracts empty for most of the period. By then he had become *Homo sapiens*, with a large brain. He had tools keen enough to give him clothes of animal skin. He had invented projectiles to widen the perimeter of his striking power: bolas, javelins with spear throwers, arrows with bows. He was using dogs to widen the perimeter of his senses in tracking. He had found what could be eaten from the sea and its shores. He could move only slowly, and was probably by no means adventurous. But hunting territory was precious, and the surplus of an expanding population had

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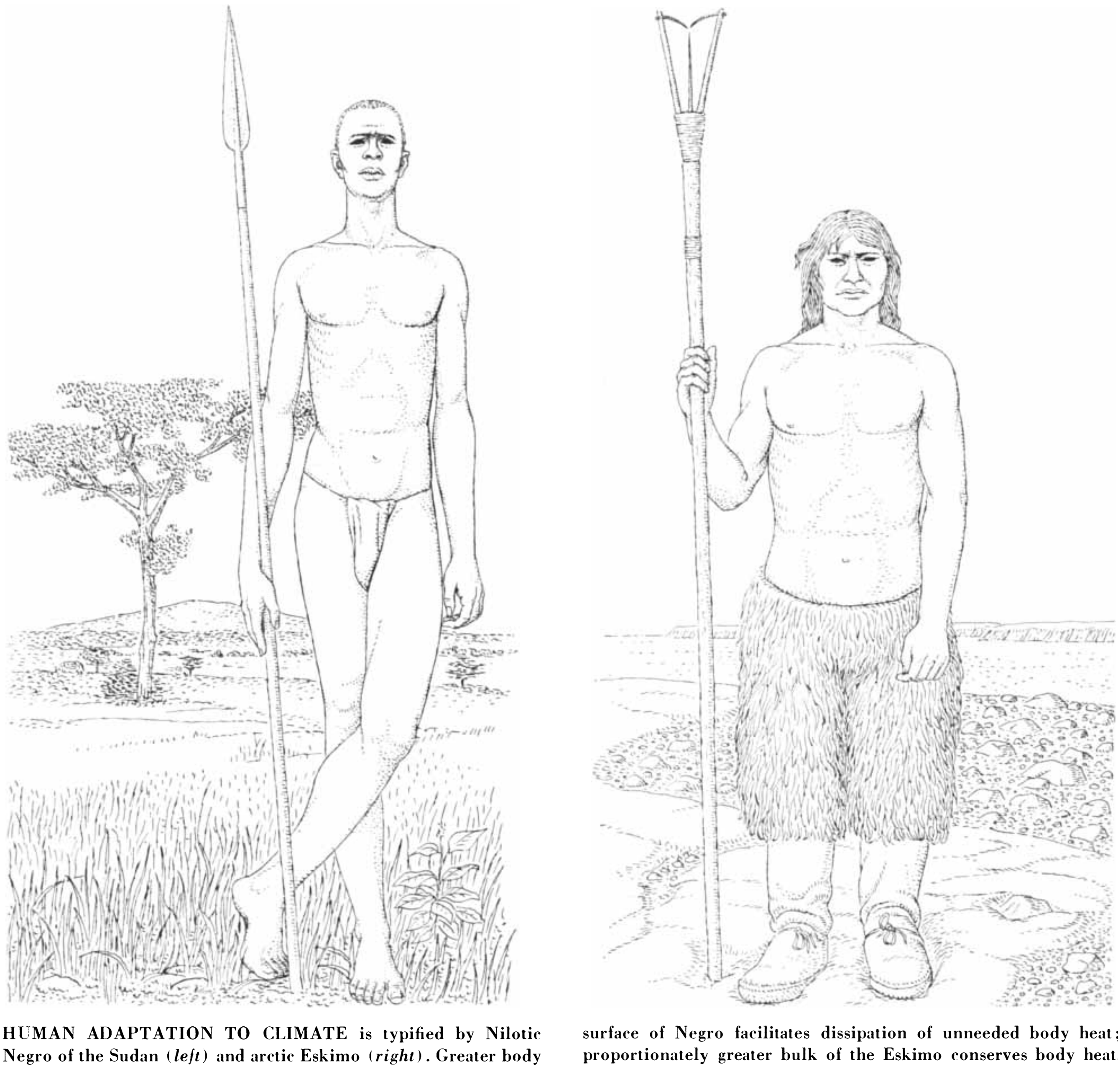
to stake out new preserves wherever there was freedom ahead. So this pressure, and man's command of nature, primitive though it still was, sent the hunters of the end of the Ice Age throughout the Old World, out into Australia, up into the far north, over the Bering Strait and down the whole length of the Americas to Tierra del Fuego. At the beginning of this dispersion we have brutes barely able to shape a stone tool; at the end, the wily, self-reliant Eskimo, with his complicated traps, weapons and sledges and his clever hunting tricks.

The great racial radiation carried out by migratory hunters culminated in the world as it was about 10,000 years ago. The Whites occupied Europe, northern and eastern Africa and the Near East, and extended far to the east in Central Asia toward the Pacific shore. Negroes occupied the Sahara, better watered then, and Pygmies the African equatorial forest; south, in the open country, were Bushmen only. Other Pygmies, the Negritos, lived in the forests of much of India and southeastern Asia; while in the open country of these areas and in Australia were men like the present Australian aborigines: brown, beetle-browed and wavy-haired. Most of the Pacific was empty. People such as the American Indians stretched from China and Mongolia over Alaska to the Straits of Magellan; the more strongly Mongoloid peoples had not yet attained their domination of the Far East.

During the whole period the human population had depended on the supply of wild game for food, and the accent had been on relative isolation of peoples and groups. Still close to nature (as we think of nature), man was in a good position for rapid small-scale evolution, both through natural selection and through the operation of chance in causing differences among widely separated tribes even if selection was not strong.

Then opened the Neolithic period, the beginning of a great change. Agriculture was invented, at first inefficient and feeble, but in our day able to feed phenomenally large populations while freeing them from looking for food. The limit on local numbers of people was gradually removed, and with it the



HUMAN ADAPTATION TO CLIMATE is typified by Nilotic Negro of the Sudan (*left*) and arctic Eskimo (*right*). Greater body surface of Negro facilitates dissipation of unneeded body heat; proportionately greater bulk of the Eskimo conserves body heat.

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BISMUTH	A-58		2	1		1	2						1*	
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COPPER	A-58	No Impurities Detectable by Spectrographic Analysis												
GOLD	A-59		1*	1*		1*	1*							
INDIUM	A-58		1*			1		1*	1					
LEAD	A-58	1*	1*	1*			1*							
SELENIUM	A-58		1*		1*					1			1*	
SILVER	A-59		1*	1*		1*					1			
SULFUR	A-58											1	1	
TELLURIUM	A-58		1*	1*										
THALLIUM	A-58		3	1		1*	1*					2	1*	
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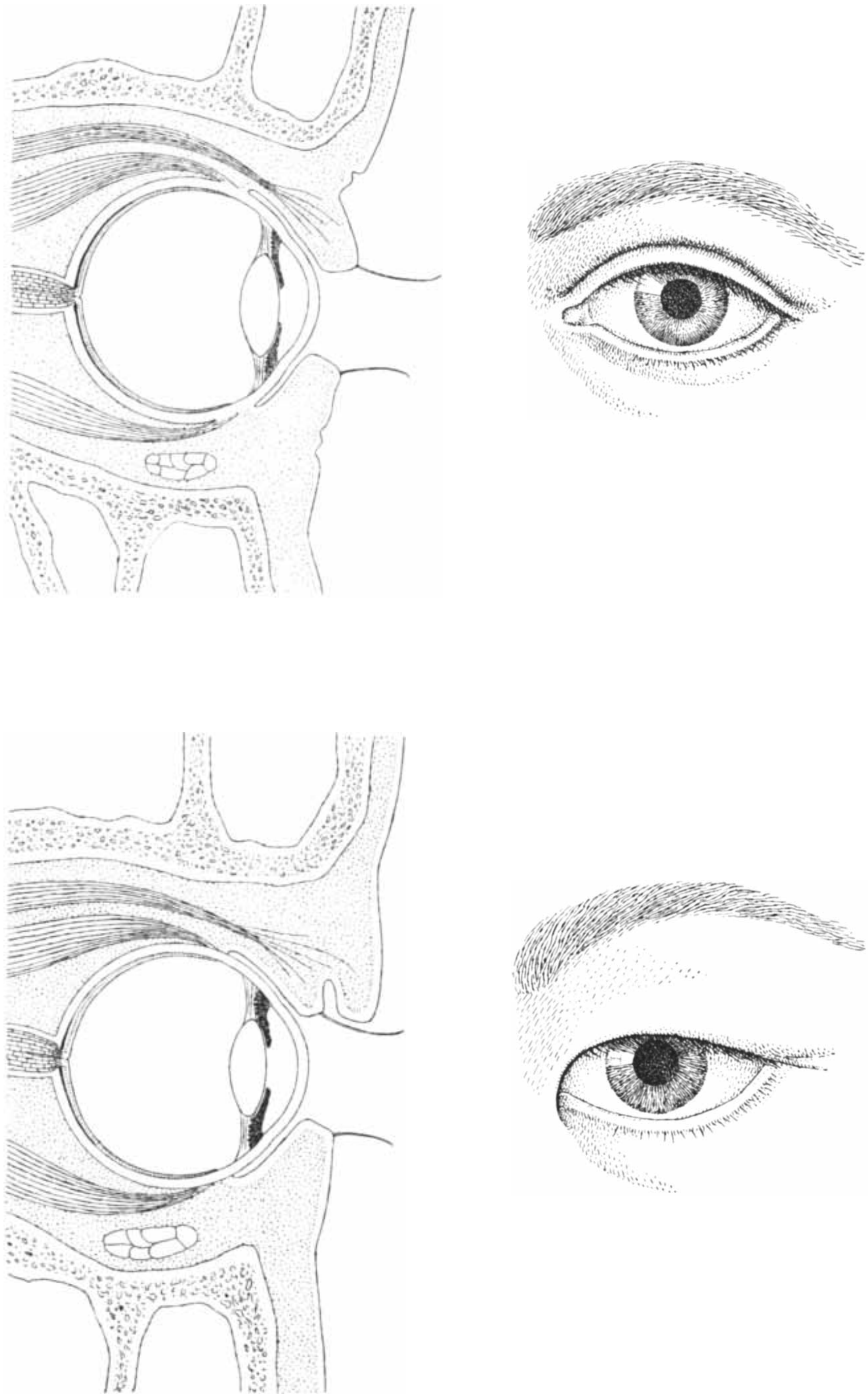
of groups and the careful observation of boundaries. Now, as there began to be surpluses available for trading, connections between communities became more useful. Later came a spreading of bonds from higher centers of trade and of authority. Isolation gave way to contact, even when contact meant war.

The change was not speedy by our standards, though in comparison with the pace of the Stone Age it seems like a

ed people much more solidly, of course. Farmers have been uprooting and displacing hunters from the time of the first planters to our own day, when Bushman survivors are still losing reservation land to agriculturalists in southwestern Africa. These Bushmen, a scattering of Australian aborigines, the Eskimos and a few other groups are the only representatives of their age still in place. On the other hand, primitive representatives of



"ALMOND" EYE OF MONGOLOID RACES is among latest major human adaptations to environment. The Mongoloid fold, shown in lower drawings, protects the eye against the severe Asian winter. Drawings at top show the Caucasian eye with its single, fatty lid.

many places after the thousands of years since they first became established there.

Nevertheless mobility increased and has increased ever since. Early woodland farmers were partly nomadic, moving every generation following exhaustion of the soil, however solidly fixed they may have been during each sojourn. The Danubians of 6,000 years ago can be traced archeologically as they made the same kind of periodic removes as central Africans, Iroquois Indians and pioneer Yankee farmers. Another side of farming—animal husbandry—gave rise to pastoral nomadism. Herders were much lighter of foot, and historically have tended to be warlike and domineering. With irrigation, villages could settle forever and evolve into the urban centers of high civilizations. Far from immobilizing man, however, these centers served as fixed bases from which contact (and conflict) worked outward.

The rest of the story is written more clearly. New crops or new agricultural methods opened new territories, such as equatorial Africa, and the great plains of the U. S., never successfully farmed by the Indians. New materials such as copper and tin made places once hopeless for habitation desirable as sources of raw material or as way stations for trade. Thus an island like Crete rose from nothing to dominate the eastern Mediterranean for centuries. Well before the earliest historians had made records, big population shifts were taking place. Our mental picture of the aboriginal world is actually a recent one. The Bantu Negroes moved into central and southern Africa, peoples of Mongoloid type went south through China and into Japan, and ancient folk of Negrito and Australoid racial nature were submerged by Caucasians in India. Various interesting but inconsequential trickles also ran hither and yon; for example, the migration of the Polynesians into the far Pacific.

The greatest movement came with the advent of ocean sailing in Europe. (The Polynesians had sailed the high seas earlier, of course, but they had no high culture, nor did Providence interpose a continent across their route at a feasible distance, as it did for Columbus.) The Europeans poured out on the world. From the 15th to the 19th centuries they compelled other civilized peoples to accept contact, and subjected or erased the uncivilized. So today, once again, we have a quite different distribution of mankind from that of 1492.

It seems obvious that we stand at the beginning of still another phase. Con-

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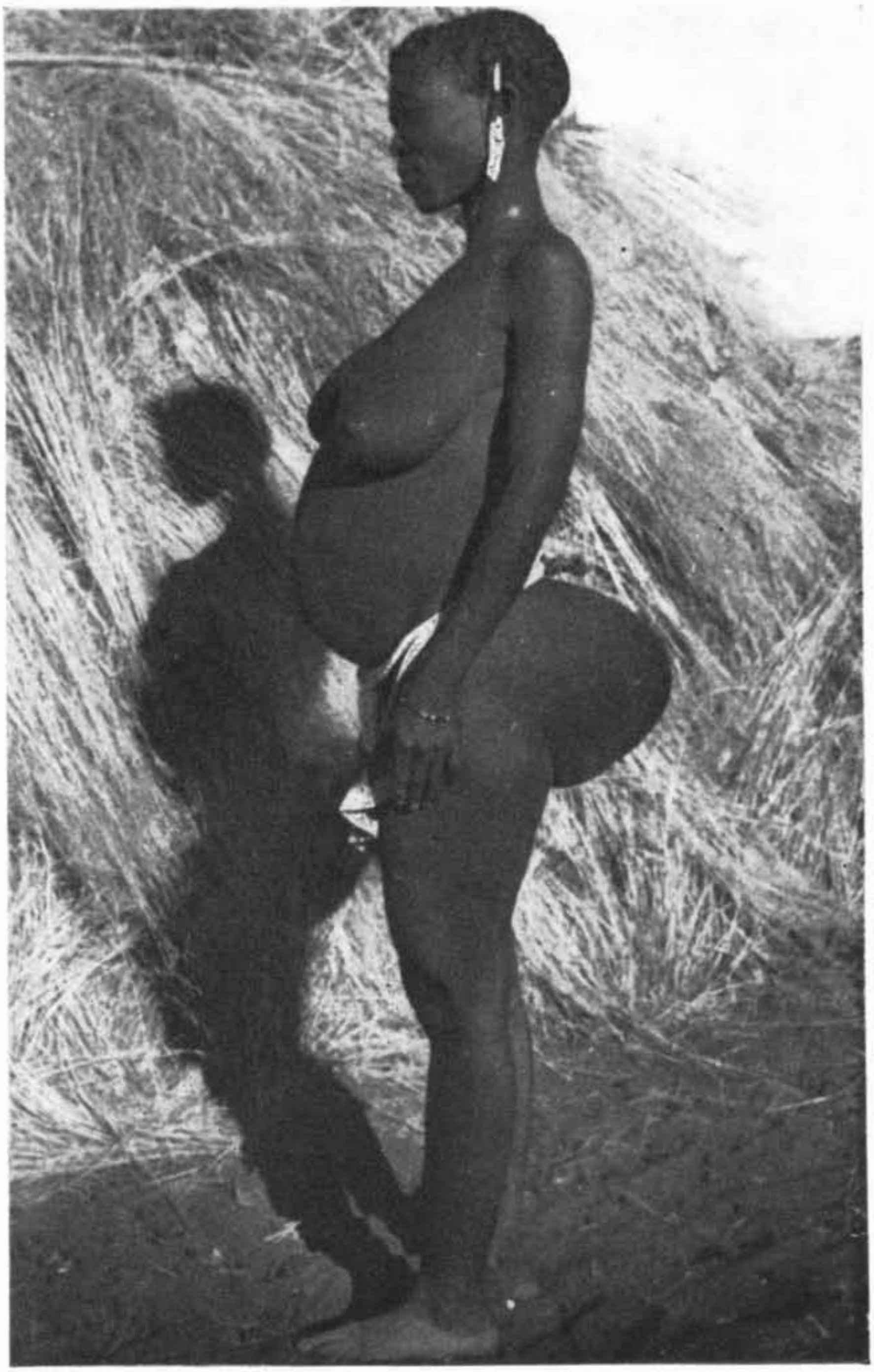
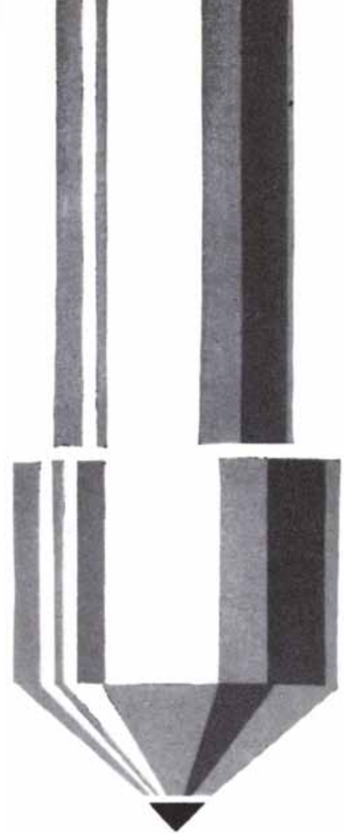
tact is immediate, borders are slamming shut and competition is fierce. Biological fitness in races is now hard to trace, and even reproduction is heavily controlled by medicine and by social values. The racial picture of the future will be determined less by natural selection and disease resistances than by success in government and in the adjustment of numbers. The end of direct European dominance in Africa and Asia seems to mean the end of any possibility of the infiltration and expansion of the European variety of man there, on the New World model. History as we know it has been largely the expansion of the European horizon and of European peoples. But the end in China of mere absorption of Occidental invention, and the passionate self-assertion of the African tribes, make it likely that racial lines and territories will again be more sharply drawn than they have been for centuries. What man will make of himself next is a question that lies in the province of prophets, not anthropologists.



STEATOPYGIA OF HOTTENTOT WOMAN, by confining accumulation of most body fat to buttocks, leaves rest of body relatively free of fat. Body can thus better dissipate heat.

Diamond-impregnated tool



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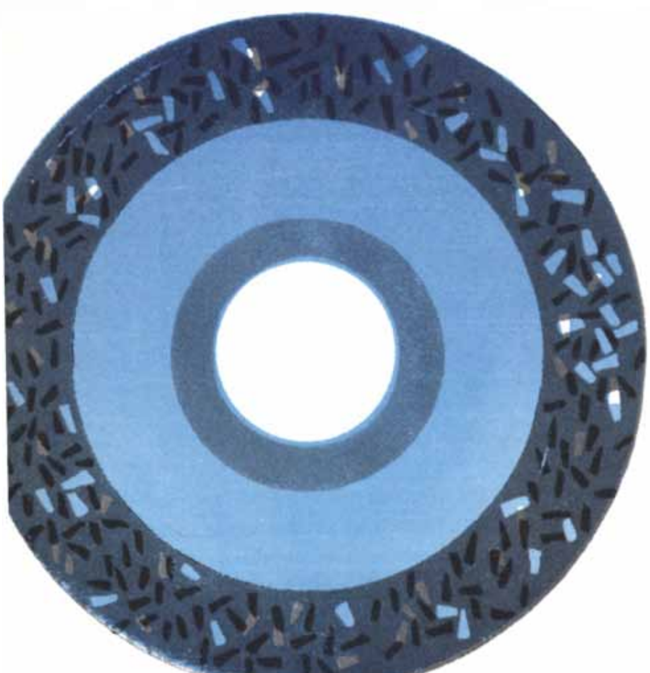

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Engraving tool

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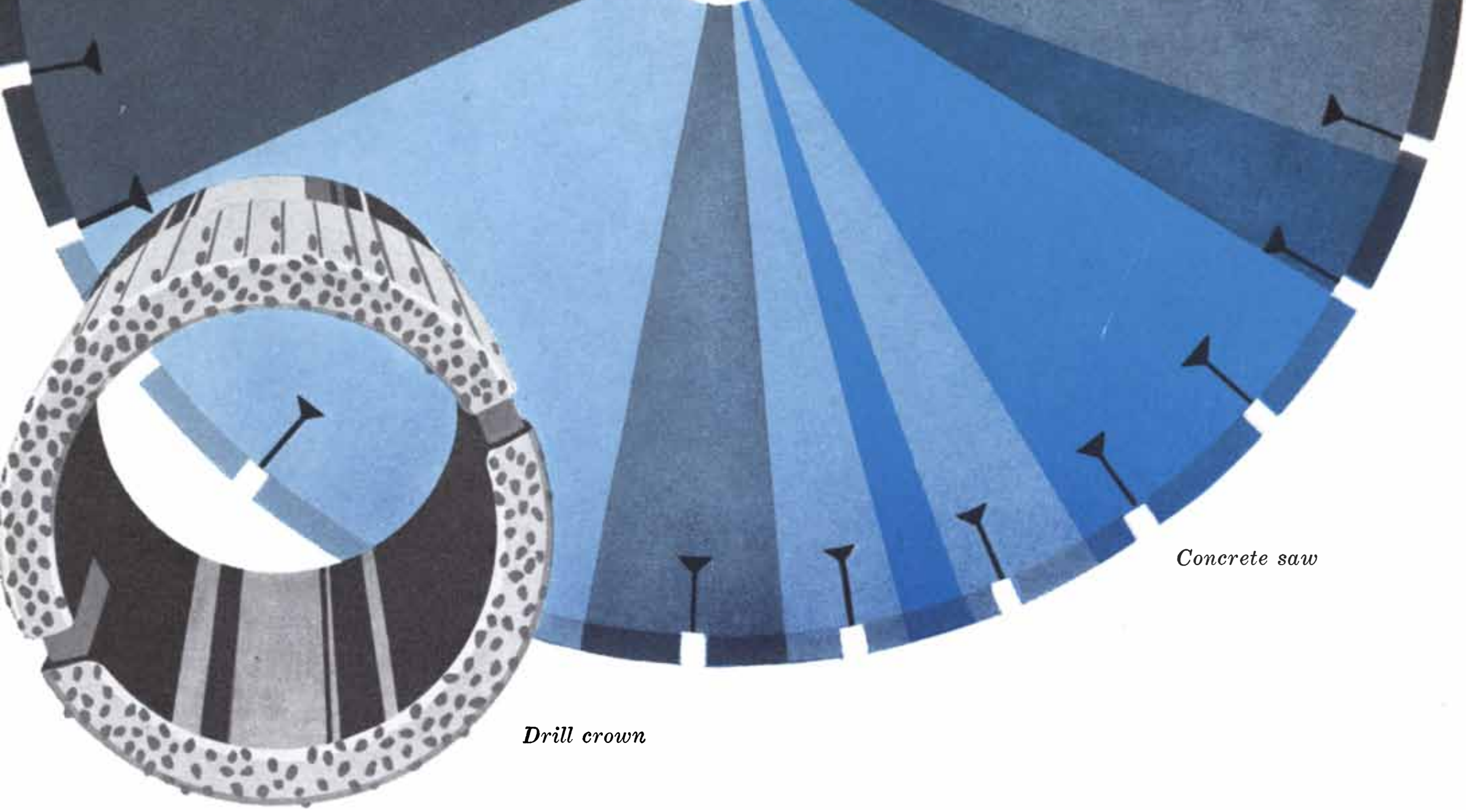

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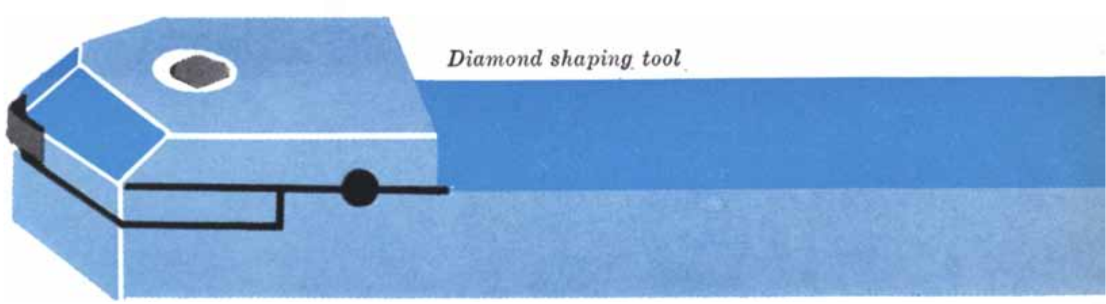

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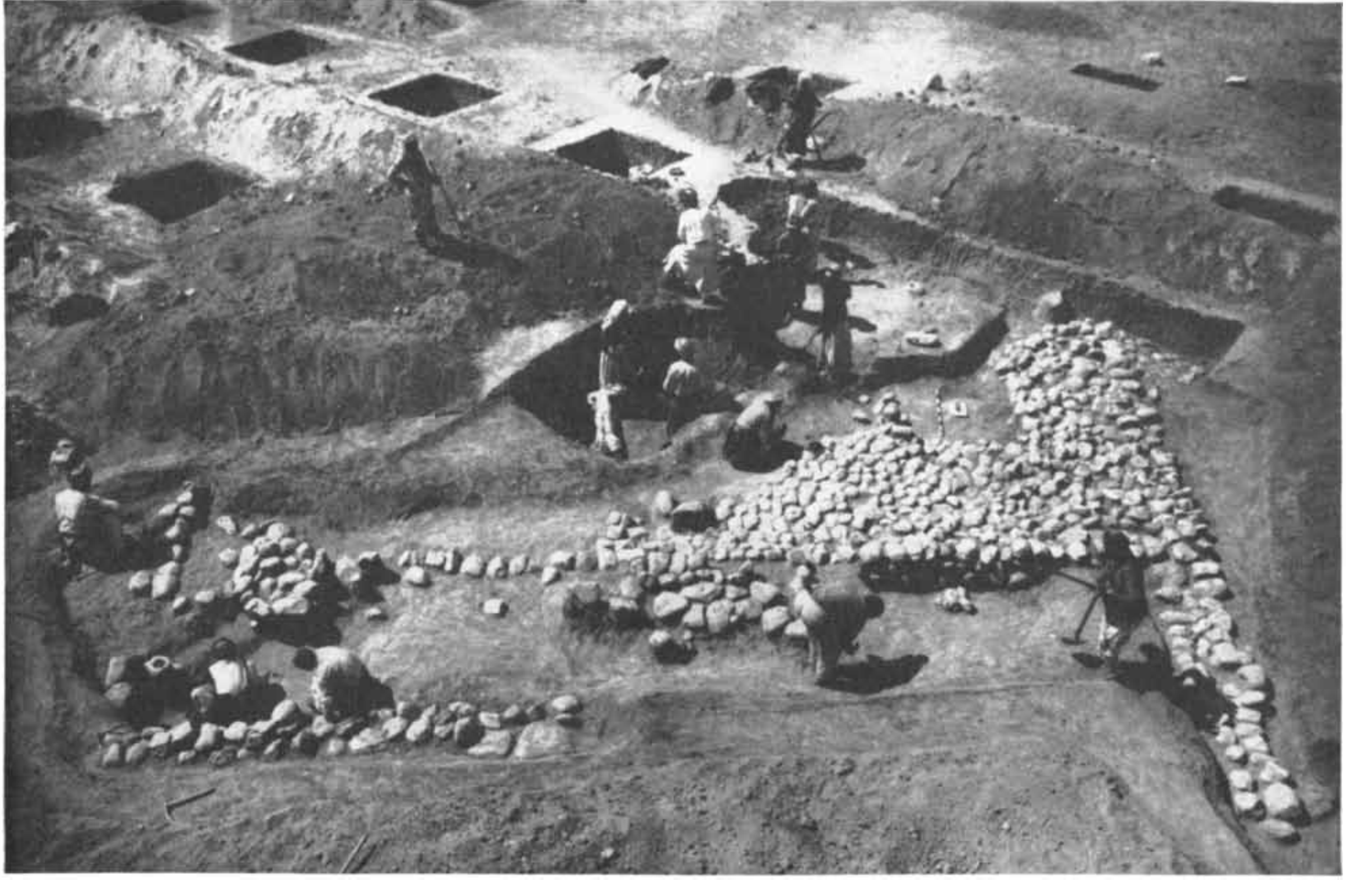


JARMO IN IRAQI KURDISTAN is the site of the earliest village-farming community yet discovered. This photograph of an upper level of excavation shows foundation and paving stones. Site was occupied for perhaps 300 years somewhere around 6750 B.C.

EXCAVATION AT KARIM SHAHIR contained confused scatter of rocks brought there by ancient men and disturbed by modern plowing. This prefarming site had no clear evidence of permanent houses, but did have skillfully chipped flints and other artifacts.

The Agricultural Revolution

Until some 10,000 years ago all men lived by hunting, gathering and scavenging. Then the inhabitants of hills in the Middle East domesticated plants and animals and founded the first villages

by Robert J. Braidwood

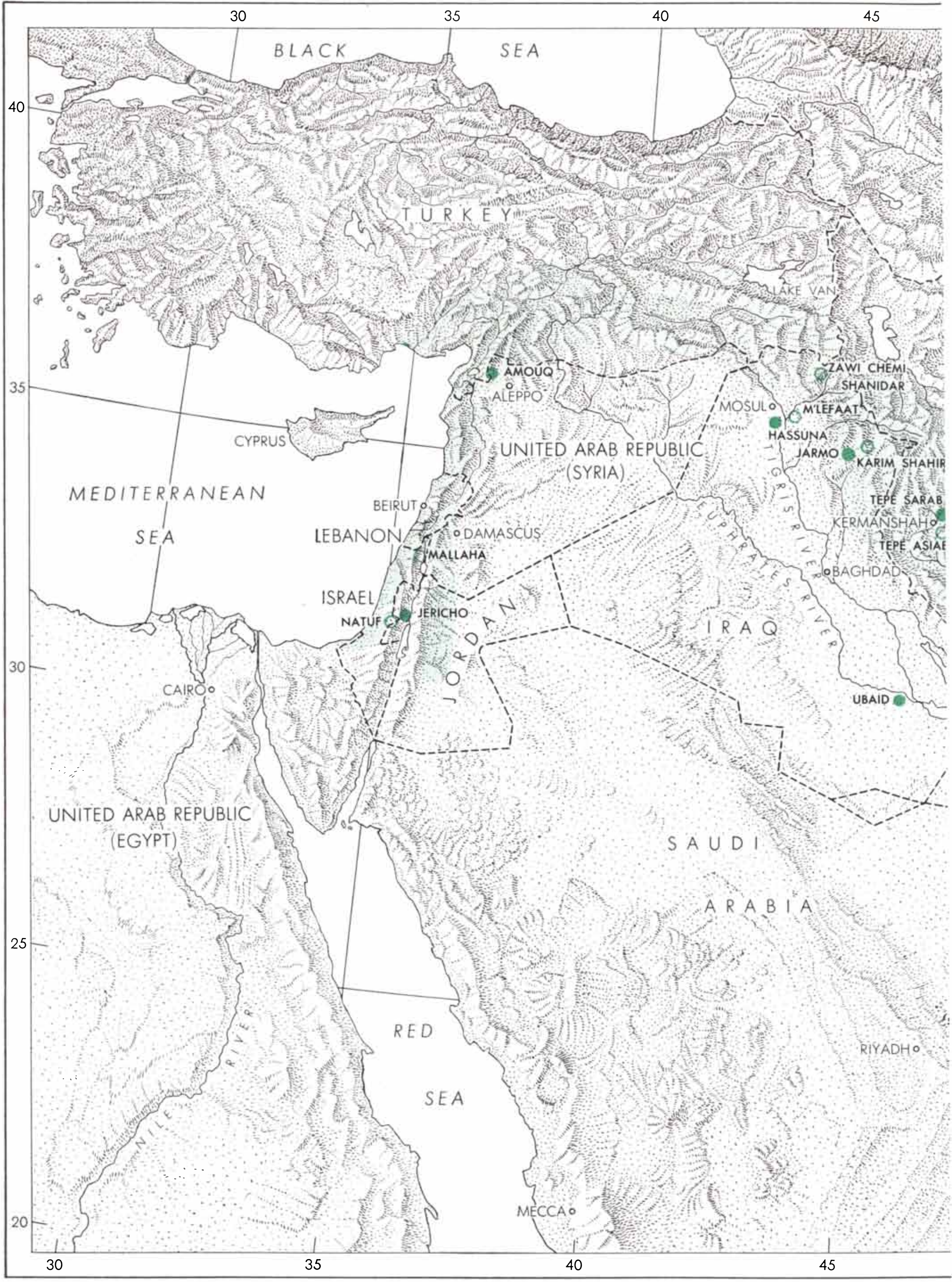
Tool-making was initiated by pre-*sapiens* man. The first comparable achievement of our species was the agricultural revolution. No doubt a small human population could have persisted on the sustenance secured by the hunting and food-gathering technology that had been handed down and slowly improved upon over the 500 to 1,000 millennia of pre-human and pre-*sapiens* experience. With the domestication of plants and animals, however, vast new dimensions for cultural evolution suddenly became possible. The achievement of an effective food-producing technology did not, perhaps, predetermine subsequent developments, but they followed swiftly: the first urban societies in a few thousand years and contemporary industrial civilization in less than 10,000 years.

The first successful experiment in food production took place in southwestern Asia, on the hilly flanks of the "fertile crescent." Later experiments in agriculture occurred (possibly independently) in China and (certainly independently) in the New World. The multiple occurrence of the agricultural revolution suggests that it was a highly probable outcome of the prior cultural evolution of mankind and a peculiar combination of environmental circumstances. It is in the record of culture, therefore, that the origin of agriculture must be sought.

About 250,000 years ago wide-wandering bands of ancient men began to make remarkably standardized stone hand-axes and flake tools which archeologists have found throughout a vast area of the African and western Eurasian continents, from London to Capetown to Madras. Cultures producing somewhat different tools spread over all of eastern Asia. Apparently the creators of these artifacts employed general, nonspecialized techniques in gathering and preparing food. As time went on, the record shows, specialization set in within these major traditions, or "genera," of tools, giving rise to roughly regional "species" of tool types. By about 75,000 years ago the tools became sufficiently specialized to suggest that they corresponded to the conditions of food-getting in broad regional environments. As technological competence increased, it became possible to extract more food from a given environment; or, to put the matter the other way around, increased "living into" a given environment stimulated technological adaptation to it.

Perhaps 50,000 years ago the mod-

AIR VIEW OF JARMO shows 3.2-acre site and surroundings. About one third of original area has eroded away. Archeologists dug the square holes in effort to trace village plan.


BLACK SEA
TURKEY
LAKE VAN
ZAWI CHEMI
SHANIDAR
AMOUQ
ALEPPO
MOSUL
M'LEFAAT
HASSUNA
JARMO
KARIM SHAHIR
CYPRUS
UNITED ARAB REPUBLIC (SYRIA)
TIGRIS RIVER
MEDITERRANEAN SEA
BEIRUT
LEBANON
DAMASCUS
MALLAHA
TEPE SARAB
KERMANSHAH
TEPE ASIAB
BAGHDAD
EUPHRATES RIVER
ISRAEL
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JERICHO
JORDAN
IRAQ
CAIRO
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MECCA

ern physical type of man appeared. The record shows concurrently the first appearance of a new genera of tools: the blade tools which incorporate a qualitatively higher degree of usefulness and skill in fabrication. The new type of man using the new tools substituted more systematic food-collection and organized hunting of large beasts for the simple gathering and scavenging of his predecessors. As time passed, the human population increased and men were able to adjust themselves to environmental niches as diverse as the tropical jungle and the arctic tundra. By perhaps 30,000 years ago they spread to the New World. The successful adaptation of human communities to their different environments brought on still greater cultural complexity and differentiation. Finally, between 11,000 and 9,000 years ago some of these communities arrived at the threshold of food production.

In certain regions scattered throughout the world this period (the Mesolithic in northwestern Europe and the Archaic in North America) was characterized by intensified food-collection: the archeological record of the era is the first that abounds in the remains of small, fleet animals, of water birds and fish, of snails and mussels. In a few places signs of plant foods have been preserved, or at least we archeologists have learned to pay attention to them. All of these remains show that human groups had learned to live into their environment to a high degree, achieving an intimate familiarity with every element in it. Most of the peoples of this era of intensified food-collecting changed just enough so that they did not need to change. There are today still a few relict groups of intensified food-collectors—the Eskimos, for example—and there were many more only a century or two ago. But on the grassy and forested uplands bordering the fertile crescent a real change was under way. Here in a climate that provided generous winter and spring rainfall, the intensified food-collectors had been accumulating a rich lore of experience with wild wheat, barley and other food plants, as well as with wild dogs,

HILLS FLANKING fertile crescent, where agricultural revolution occurred, are indicated in color. Hatched areas are probably parts of this "nuclear" zone of food-producing revolution. Sites discussed in this article are indicated by large circles. Open circles are prefarming sites; solid circles indicate that food production was known there.

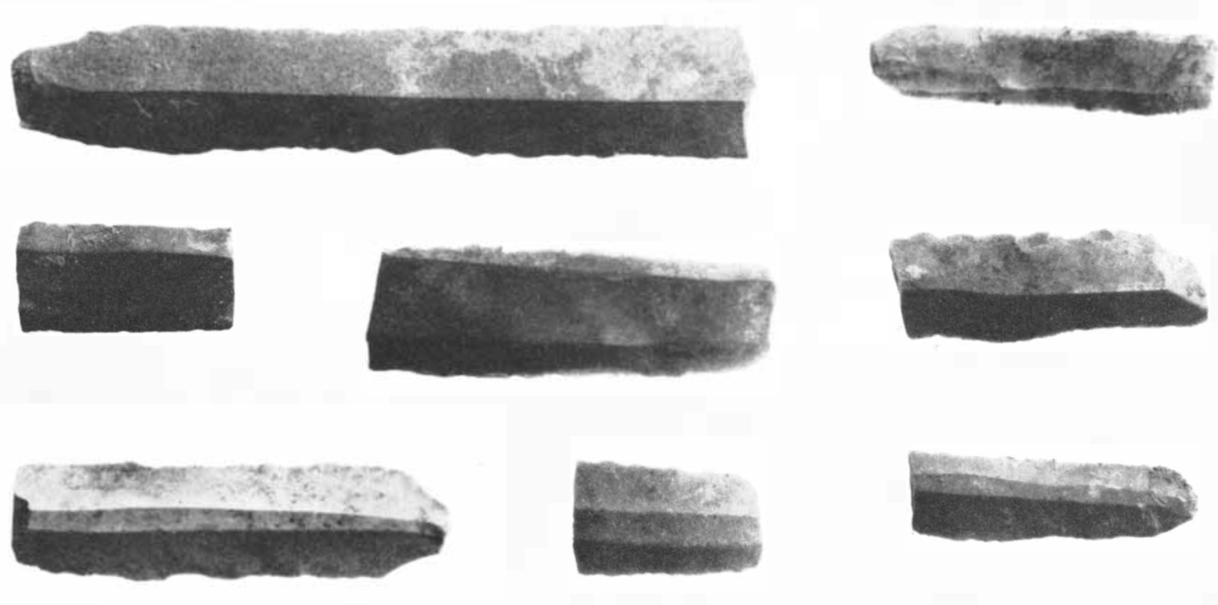
goats, sheep, pigs, cattle and horses. It was here that man first began to control the production of his food.

Not long ago the proponents of environmental determinism argued that the agricultural revolution was a response to the great changes in climate which accompanied the retreat of the last glaciation about 10,000 years ago. However, the climate had altered in equally dramatic fashion on other occasions in the past 75,000 years, and the potentially domesticable plants and animals were surely available to the bands of food-gatherers who lived in southwestern Asia and similar habitats in various parts of the globe. Moreover, recent studies have revealed that the climate did not change radically where farming began in the hills that flank the fertile crescent. Environmental determinists have also argued from the "theory of propinquity" that the isolation of men along with appropriate plants and animals in desert oases started the process of domestication. Kathleen M. Kenyon of the University of London, for example, advances the lowland oasis of Jericho as a primary site of the agricultural revolution [see "Ancient Jericho," by Kathleen M. Kenyon; SCIENTIFIC AMERICAN, April, 1954].

In my opinion there is no need to complicate the story with extraneous "causes." The food-producing revolution seems to have occurred as the culmination of the ever increasing cultural differentiation and specialization of human communities. Around 8000 B.C. the inhabitants of the hills around the fertile crescent had come to know their habitat so well that they were beginning to domesticate the plants and animals they had been collecting and hunting. At slightly later times human cultures reached the corresponding level in Central America and perhaps in the Andes, in southeastern Asia and in China. From these "nuclear" zones cultural diffusion spread the new way of life to the rest of the world.

In order to study the agricultural revolution in southwestern Asia I have since 1948 led several expeditions, sponsored by the Oriental Institute of the University of Chicago, to the hills of Kurdistan north of the fertile crescent in Iraq and Iran. The work of these expeditions has been enriched by the collaboration of botanists, zoologists and geologists, who have alerted the archeologists among us to entirely new kinds of evidence. So much remains to be done, however, that we can describe in only a tentative and quite incomplete fashion how food production began. In part, I must freely admit, my reconstruction depends upon extrapolation backward from what I know had been achieved soon after 9,000 years ago in southwestern Asia.

The earliest clues come from sites of the so-called Natufian culture in Palestine, from the Kurdistan site of Zawi Chemi Shanidar, recently excavated by Ralph S. Solecki of the Smithsonian Institution, from our older excavations at Karim Shahir and M'lefaat in Iraq, and from our current excavations at Tepe Asiab in Iran [*see map on preceding two pages*]. In these places men appear to have moved out of caves, although perhaps not for the first time, to live in at least semipermanent communities. Flint sickle-blades occur in such Natufian locations as Mallaha, and both the Palestine and Kurdistan sites have yielded milling and pounding stones—strong indications that the people reaped and ground wild cereals and other plant foods. The artifacts do not necessarily establish the existence of anything more than intensified or specialized food-collecting. But these people were at home in a landscape in which the grains grew wild, and they may have begun to cultivate them in open meadows. Excavations of later village-farming communities, which have definitely been identified as such, reveal versions of the same artifacts that are only slightly more developed than those from Karim Shahir and other earlier sites. We are constantly finding additional evidence that will eventually make the picture clearer. For example, just this spring at Tepe Asiab we found many coprolites (fossilized excrement) that appear to be of human origin. They contain abundant impressions of plant and animal foods, and when analyzed in the laboratory they promise to be a gold mine of clues to the diet of the Tepe



SICKLE BLADES FROM JARMO are made of chipped flint. They are shown here approximately actual size. When used for harvesting grain, several were mounted in a haft of wood or bone. Other Jarmo flint tools show little advance over those found at earlier sites.

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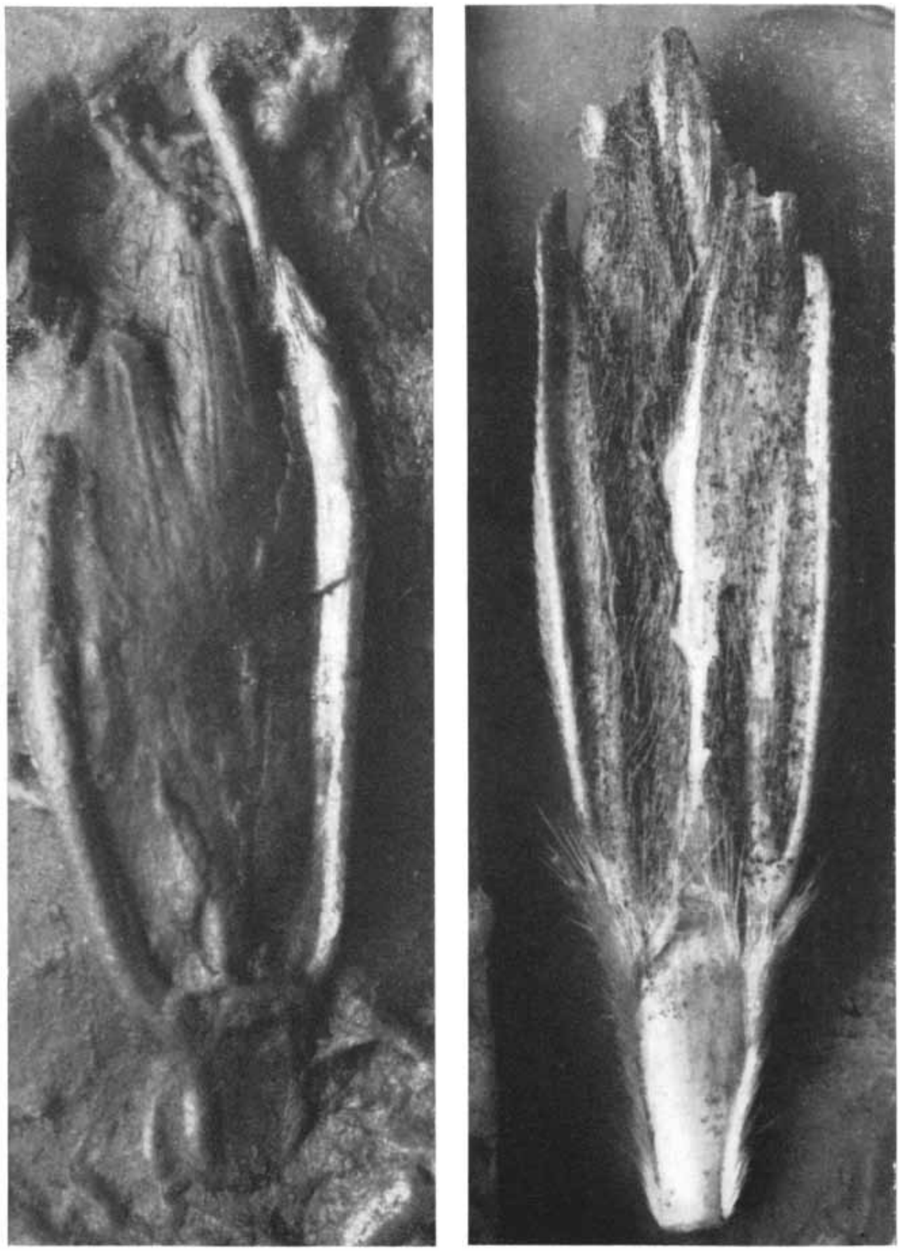
Asiab people. The nature of these antiquities" suggests how the study of the agricultural revolution differs from the archeology of ancient cities and tombs.

The two earliest indisputable village-farming communities we have so far excavated were apparently inhabited between 7000 and 6500 B.C. They are on the inward slopes of the Zagros mountain crescent in Kurdistan. We have been digging at Jarmo in Iraq since 1948 [see "From Cave to Village," by Robert J. Braidwood; SCIENTIFIC AMERICAN, October, 1952], and we started our investigations at Tepe Sarab in Iran only last spring. We think there are many sites of the same age in the hilly-flanks zone, but these two are the only ones we have so far been able to excavate. Work should also be done in this zone in southern Turkey, but the present interpretation of the Turkish antiquities law discourages our type of "problem-oriented" research, in which the investigator must take most of the ancient materials back to his laboratory. I believe that these northern parts of the basins of the Tigris and Euphrates rivers and the Cilician area of Turkey will one day yield valuable information.

Although Jarmo and Tepe Sarab are 120 miles apart and in different drainage systems, they contain artifacts that are remarkably alike. Tepe Sarab may have been occupied only seasonally, but Jarmo was a permanent, year-round settlement with about two dozen mud-walled houses that were repaired and re-

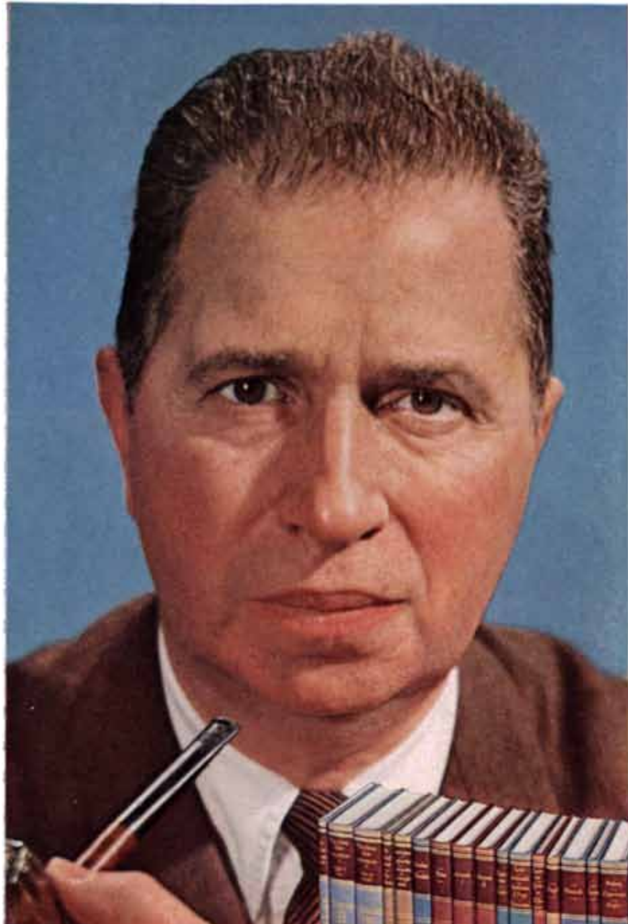


JARMO WHEAT made imprint upon clay. Cast of imprint (*left*) resembles spikelet of present-day wild wheat *Triticum dicoccoides* (*right*). Specimens are enlarged seven times.

KERNELS OF JARMO WHEAT were carbonized in fires of ancient village. They resemble kernels of wild wheat growing in area today. They are enlarged approximately four times.

built frequently, creating about a dozen distinct levels of occupancy. We have identified there the remains of two-row barley (cultivated barley today has six rows of grains on a spike) and two forms of domesticated wheat. Goats and dogs, and possibly sheep, were domesticated. The bones of wild animals, quantities of snail shells and acorns and pistachio nuts indicate that the people still hunted and collected a substantial amount of food. They enjoyed a varied, adequate and well-balanced diet which was possibly superior to that of the people living in the same area today. The teeth of the Jarmo people show even milling and no marginal enamel fractures. Thanks apparently to the use of querns and rubbing stones and stone mortars and pestles, there were no coarse particles in the diet that would cause excessive dental erosion. We have calculated that ap-

CARBONIZED BARLEY KERNELS from Jarmo, enlarged four times, are from two-row grain. The internodes attached to kernels at right indicate tough spikes of cultivated barley.



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Director of the Institute for Philosophical Research
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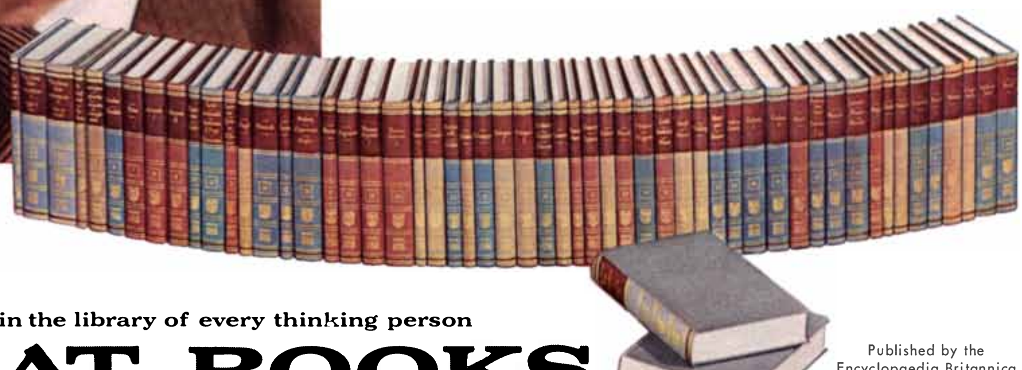

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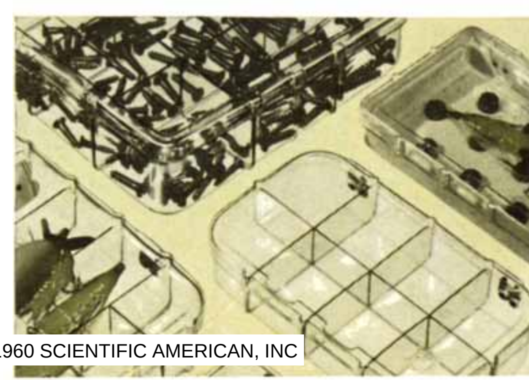

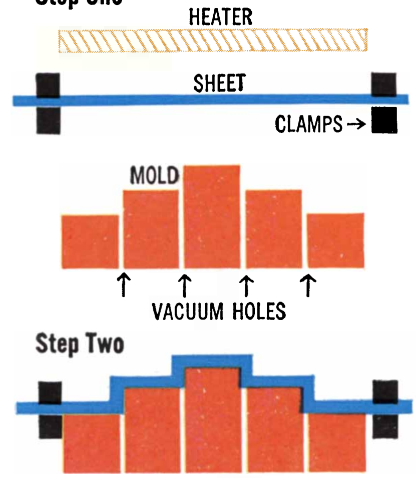

NOTE: The above diagrams depict a simple vacuum-forming operation. There are many variations of this method, including some in which air pressure or mechanical pressure replaces the use of a vacuum.

tions, such as signs, clear-transparent sheet may be used, with the decoration being applied either before forming (by use of distortion printing) or after forming. It should be noted that even shapes which at first appear impossible to vacuum form can be produced by this method. For example, by using a "plug-assist" (to permit a deep draw), wastebaskets 8½" in diameter and 11½" deep have been vacuum formed from sheet of Tenite Butyrate. Similarly, spherical globes for toys and outdoor lanterns have been produced at low cost by vacuum forming two hemispheres and then solvent-cementing them together.

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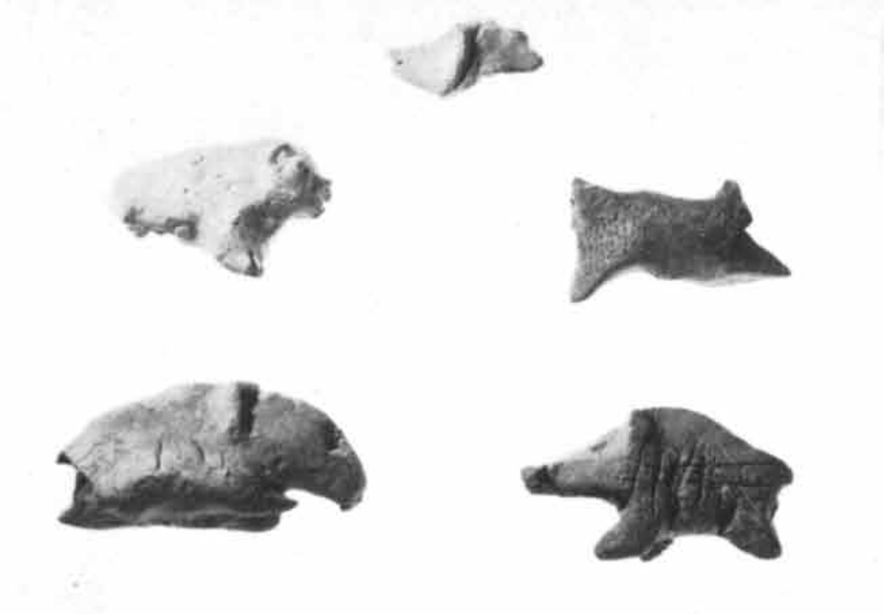


CLAY FIGURES from Sarab, shown half size, include boar's head (*top*), what seems to be lion (*upper left*), two-headed beast (*upper right*), sheep (*bottom left*) and boar.

proximately 150 people lived in Jarmo. The archeological evidence from the area indicates a population density of 27 people per square mile, about the same as today. Deforestation, soil deterioration and erosion, the results of 10,000 years of human habitation, tend to offset whatever advantages of modern tools and techniques are available to the present population.

Stone vessels of fine craftsmanship appear throughout all levels at Jarmo, but portable, locally made pottery vessels occur only in the uppermost levels. A few impressions on dried mud indicate that the people possessed woven baskets or rugs. The chipped flint tools of Jarmo and Tepe Sarab, in both normal and microlithic sizes, are direct and not very distant descendants of those at Karim Shahir and the earlier communities. But the two farming villages exhibit a geometric increase in the variety of materials of other types in the archeological catalogue. Great numbers of little clay figurines of animals and pregnant women (the "fertility goddesses") hint at the growing nonutilitarian dimensions of life. In both communities the people for

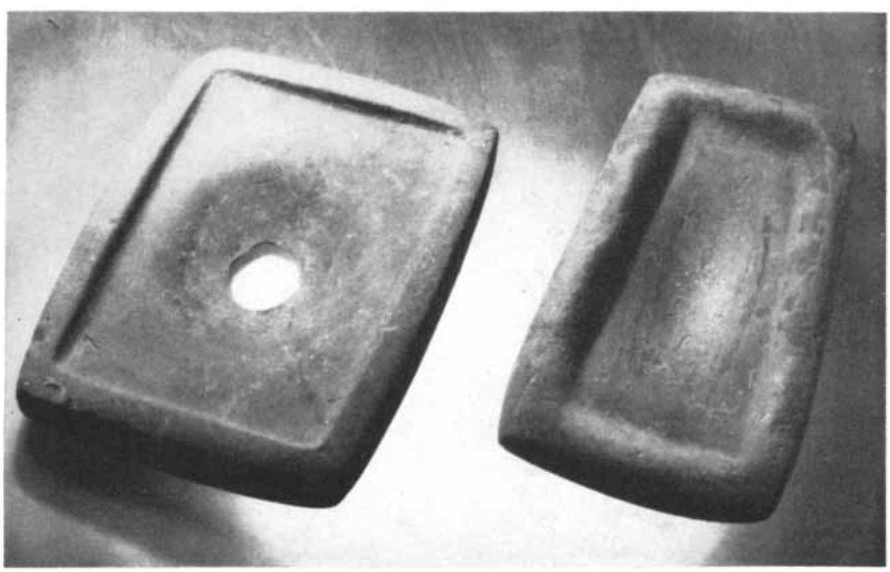
"FERTILITY GODDESS" or "Venus" from Tepe Sarab is clay figure shown actual size. Artist emphasized parts of body suggesting fertility. Grooves in leg indicate musculature.

the first time had tools of obsidian, a volcanic glass with a cutting edge much sharper and harder than stone. The obsidian suggests commerce, because the nearest source is at Lake Van in Turkey, some 200 miles from Jarmo. The sites have also yielded decorative shells that could have come only from the Persian Gulf.

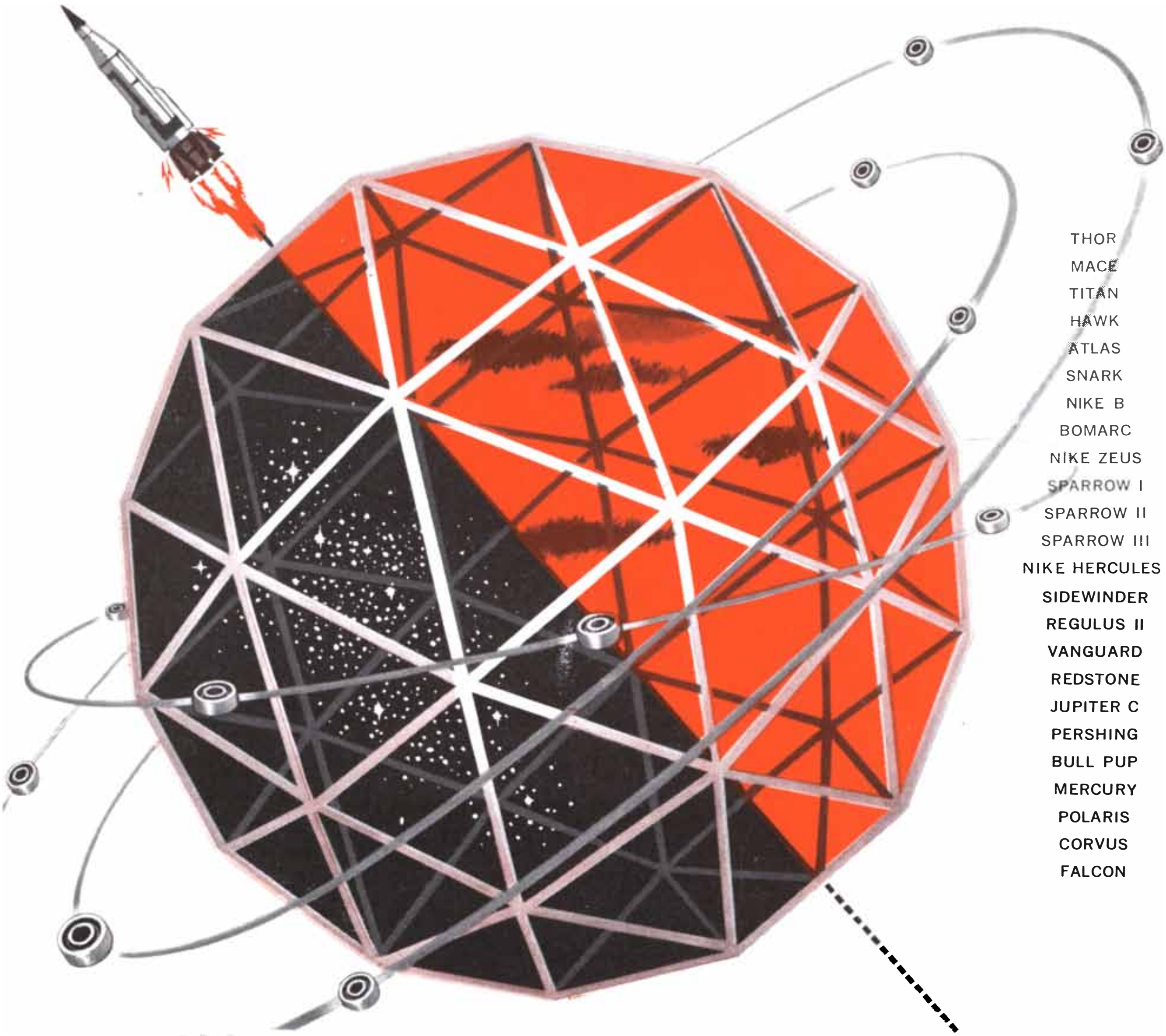
For an explanation of how plants and animals might have been domesticated between the time of Karim Shahir and of Jarmo, we have turned to our colleagues in the biological sciences. As the first botanist on our archeological team, Hans Helbaek of the Danish National Museum has studied the carbonized remains of plants and the imprints of grains, seeds and other plant parts on baked clay and adobe at Jarmo and other sites. He believes that the first farmers, who grew both wheat and barley, could only have lived in the highlands around the fertile crescent, because that is the only place where both plants grew wild. The region is the endemic home of wild wheat. Wild barley, on the other hand, is widely scattered from central Asia to the Atlantic, but no early agriculture was based upon barley alone.

Helbaek surmises that from the beginning man was unintentionally breeding the kind of crop plants he needed. Wild grasses have to scatter their seeds over a large area, and consequently the seed-holding spike of wild wheat and barley becomes brittle when the plant ripens. The grains thus drop off easily. A few wild plants, however, exhibit a recessive gene that produces tough spikes that do not become brittle. The grains hang on, and these plants do not reproduce well in nature. A man harvesting wild wheat and barley would necessarily reap plants with tough spikes and intact heads. When he finally did sow seeds, he would naturally have on hand a large proportion of grains from tough-spike plants—exactly the kind he needed for farming. Helbaek points out that early farmers must soon have found it advantageous to move the wheat down from the mountain slopes, from 2,000 to 4,300 feet above sea level (where it occurs in nature), to more level ground near a reliable water supply and other accommodations for human habitation. Still, the plant had to be kept in an area with adequate winter and spring rainfall. The piedmont of the fertile crescent provides even today precisely these conditions. Since the environment there differs from the native one, wheat plants with mutations and recessive characteristics, as well as hybrids and other freaks, that were ill adapted to the uplands would have had a chance to survive. Those that increased the adaptation of wheat to the new environment would have made valuable contributions to the gene pool. Domesticated wheat, having lost the ability to disperse its seeds, became totally dependent upon man. In turn, as Helbaek emphasizes, man became the servant of his plants, since much of his routine of life now depended upon the steady and ample supply of vegetable food from his fields.

The traces and impressions of the grains at Jarmo indicate that the process of domestication was already advanced at that place and time, even though human selection of the best seed



STONE PALETTES from Jarmo show that the men who lived there were highly skilled in working stone. The site has also yielded many beautifully shaped stone bowls and mortars.



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POTTERY MADE AT JARMO, in contrast to the stonework, is simple. It is handmade, vegetable-tempered, buff or orange-buff in color. It shows considerable technical competence.

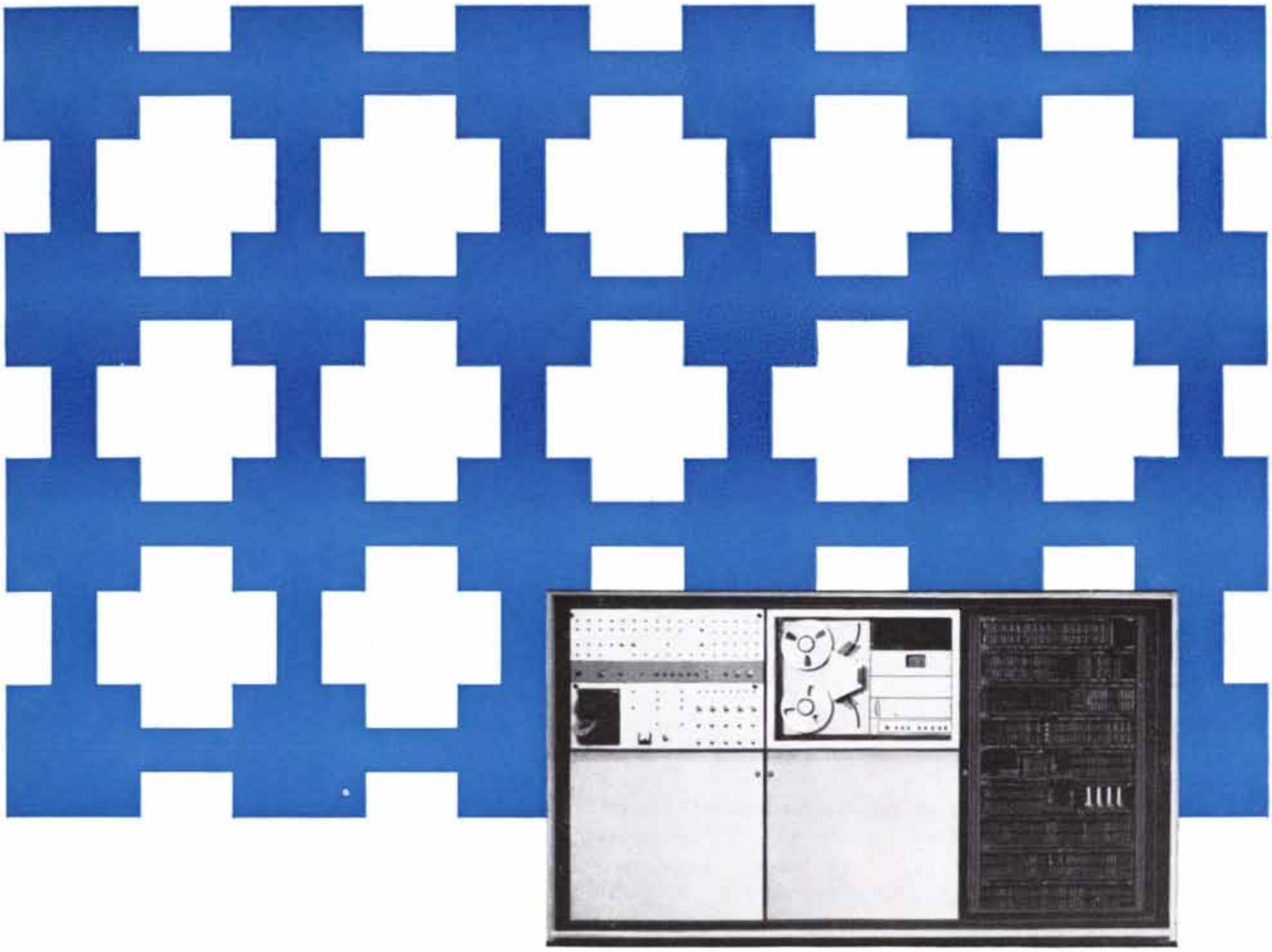
had not yet been carried far. Carbonized field peas, lentils and vetchling have also been found at Jarmo, but it is not certain that these plants were under cultivation.

Apparently farming and a settled community life were cultural prerequisites for the domestication of animals. Charles A. Reed, zoologist from the University of Illinois, has participated in the Oriental Institute expeditions to Iraq and Iran and has studied animal skeletons we have excavated. He believes that animal domestication first occurred in this area, because wild goats, sheep, cattle, pigs, horses, asses and dogs were all present there, and settled agricultural communities had already been established. The wild goat (*Capra hircus aegagrus*, or pasang) and sheep (*Ovis orientalis*), as well as the wild ass (onager) still persist in the highlands of southwestern Asia. Whether the dog was the offspring of a hypothetical wild dog, of the pariah dog or of the wolf is still uncertain, but it was undoubtedly the first animal to be domesticated. Reed has not been able to identify any dog remains at Jarmo, but doglike figurines, with tails upcurled, show almost certainly that dogs were established in the domestic scene. The first food animal to be domesticated was the goat; the shape of goat horns found at Jarmo departs sufficiently from that of the wild animal to certify generations of domestic breeding. On the other hand, the scarcity of remains of cattle at Jarmo indicates that these animals had not yet been domesticated; the wild cattle in the vicinity were probably too fierce to submit to captivity.

No one who has seriously considered the question believes that food needs motivated the first steps in the domestication of animals. The human proclivity for keeping pets suggests itself as a much simpler and more plausible explanation. Very young animals living in the environment may have attached themselves to people as a result of "imprinting," which is the tendency of the animal to follow the first living thing it sees and hears during a critically impressionable period in its infancy [see "'Imprinting' in Animals," by Eckhard H. Hess; SCIENTIFIC AMERICAN, March, 1958].

Young animals were undoubtedly also captured for use as decoys on the hunt. Some young animals may have had human wet nurses—a practice in some primitive tribes even today. After goats were domesticated, their milk would have been available for orphaned wild calves, colts and other creatures. Adult wild animals, particularly goats and sheep, which sometimes approach human beings in search of food, might also have been tamed.

Reed defines the domesticated animal as one whose reproduction is controlled by man. In his view the animals that were domesticated were already physiologically and psychologically preadapted to being tamed without loss of their ability to reproduce. The individual animals that bred well in captivity



would have contributed heavily to the gene pool of each succeeding generation. When the nucleus of a herd was established, man would have automatically selected against the aggressive and unmanageable individuals, eventually producing a race of submissive creatures. This type of unplanned breeding no doubt long preceded the purposeful artificial selection that created different breeds within domesticated species. It is apparent that goats, sheep and cattle were first husbanded as producers of meat and hides; wild cattle give little milk, and wild sheep are not woolly but hairy. Only much later did the milk- and wool-producing strains emerge.

As the agricultural revolution began to spread, the trend toward ever increasing specialization of the intensified food-collecting way of life began to reverse itself. The new techniques were capable of wide application, given suitable adaptation, in diverse environments. Archeological remains at Hassuna, a site near the Tigris River somewhat later than Jarmo, show that the people were exchanging ideas on the manufacture of pottery and of flint and obsidian projectile points with people in the region of the Amouq in Syro-Cilicia. The basic elements of the food-producing complex —wheat, barley, sheep, goats and probably cattle—in this period moved west beyond the bounds of their native habitat to occupy the whole eastern end of the Mediterranean. They also traveled as far east as Anau, east of the Caspian Sea. Localized cultural differences still existed, but people were adopting and adapting more and more cultural traits from other areas. Eventually the new way of life traveled to the Aegean and beyond into Europe, moving slowly up such great river valley systems as the Dnieper, the Danube and the Rhone, as well as along the coasts. The intensified food-gatherers of Europe accepted the new way of life, but, as V. Gordon Childe has pointed out, they "were not slavish imitators: they adapted the gifts from the East . . . into a new and organic whole capable of developing on its own original lines." Among other things, the Europeans appear to have domesticated rye and oats that were first imported to the European continent as weed plants contaminating the seed of wheat and barley. In the comparable diffusion of agriculture from Central America, some of the peoples to the north appear to have rejected the new ways, at least temporarily.

By about 5000 B.C. the village-farming way of life seems to have been fingering down the valleys toward the alluvial bottom lands of the Tigris and Euphrates. Robert M. Adams believes that there may have been people living in the lowlands who were expert in collecting food from the rivers. They would have taken up the idea of farming from people who came down from the higher areas. In the bottom lands a very different climate, seasonal flooding of the land and small-scale irrigation led agriculture through a significant new technological transformation. By about 4000 B.C. the people of southern Mesopotamia had achieved such increases in productivity that their farms were beginning to support an urban civilization. The ancient site at Ubaid is typical of this period [see "The Origin of Cities," by Robert M. Adams; page 153].

Thus in 3,000 or 4,000 years the life of man had changed more radically than in all of the preceding 250,000 years. Before the agricultural revolution most men must have spent their waking moments seeking their next meal, except when they could gorge following a great kill. As man learned to produce food, instead of gathering, hunting or collecting it, and to store it in the grain bin and on the hoof, he was compelled as well as enabled to settle in larger communities. With human energy released for a whole spectrum of new activities, there came the development of specialized nonagricultural crafts. It is no accident that such innovations as the discovery of the basic mechanical principles, weaving, the plow, the wheel and metallurgy soon appeared.

No prehistorian worth his salt may end or begin such a discussion without acknowledging the present incompleteness of the archeological record. There is the disintegration of the perishable materials that were primary substances of technology at every stage. There is the factor of chance in archeological discovery, of vast areas of the world still incompletely explored archeologically, and of inadequate field techniques and interpretations by excavators. There are the vagaries of establishing a reliable chronology, of the whimsical degree to which "geobiochemical" contamination seems to have affected our radioactive-carbon age determinations. There is the fact that studies of human paleo-environments by qualified natural historians are only now becoming available. Writing in the field, in the midst of an exciting season of excavation, I would not be surprised if the picture I have presented here needs to be altered somewhat by the time that this article has appeared in print.

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It is the purpose of this new series to make product information more useful to those concerned with chemical processing. Instead of presenting new chemicals as isolated items, this series will present products as they are related to classes of processing problems.

Sometimes these products will be new, or newsworthy. Sometimes they will be established products with new or continuing relevance to today's problems. Always they will be presented in their relation to a particular area of interest to processors.

EMULSIFICATION

Dow products relating to emulsification will be covered in this first series of advertisements. On the next page, the first ad in the series describes alkanolamine soaps as emulsifiers, and methylcellulose as a thickener and surfactant. Later advertisements will present other emulsifier intermediates and additives, plus new Dow emulsifiers soon to be announced.

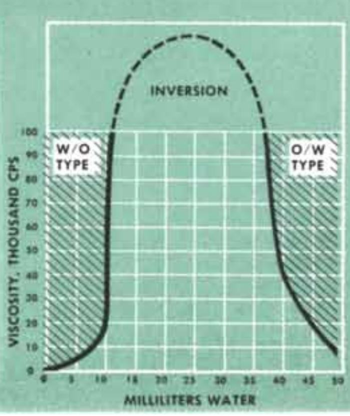
DOW | **THE DOW CHEMICAL COMPANY** • Midland, Michigan

Dow **C.P.I.** *file* **1**

EMULSIFICATION

PRIMARY CONSIDERATIONS in the choice of emulsification materials are compatibility of the components, viscosity, stability, particle size, and toxicity. On the next page are shown the properties of methylcellulose, a highly effective, safe emulsifier. Described below is a formulating technique with Dow alkanolamines contributing to higher viscosity, smaller particle size, and thus greater stability.

INVERSION, the technique by which the oil and water phases of an emulsion change relationships, is recommended for use in all methods of alkanolamine emulsion formulating when maximum stability is desired. Graph shows changeover of a triethanolamine emulsion. The fatty acid was dissolved in the oil and the TEA was dissolved in the resulting acid-oil solution. Then, with stirring, small increments of water were added. The graph is characteristic of all alkanolamines if the same procedure is followed.



INTERMEDIATES

ALKANOLAMINE SOAPS—NONCORROSIVE, STABLE, SAFE FOR SKIN AND TEXTILES

MOST IMPORTANT of the Dow alkanolamines, all water soluble, are monoethanolamine (MEA), triethanolamine (TEA), monoisopropanolamine (MIPA), and diisopropanolamine (DIPA). Compared to other amines in the alkanolamine series, these compounds produce emulsions having finer particle size and greater stability.

Being essentially neutral, emulsions prepared with alkanolamines are relatively noncorrosive to metals and are not harmful to the skin nor to textiles. Frequently a natural oil will contain enough organic acid so that in the presence of an alkanolamine it will emulsify readily in water. Alkanolamine-fatty acid emulsions are easily prepared from such common acids as oleic, stearic, and palmitic. End use will determine the acid used. For example, oleic acid yields low viscosity, stearic higher viscosity. Proven uses for alkanolamine soaps include metal cutting and buffing compounds; floor, furniture, and car polishes; pharmaceutical ointments, skin creams and lotions; insecticide sprays, textile scouring, and wetting agents.

For a comprehensive coverage of the Dow alkanolamines, write for the Dow booklet "Alkanolamine Soaps in Emulsions."

CHOICE OF FATTY ACID HAS STRONG EFFECT ON EMULSION VISCOSITY

FATTY ACID	VISCOSITY (cps) at 77°F.
Oleic	240
Palmitic	450
Stearic	2,000

CHOICE OF AMINE HAS LESS EFFECT ON EMULSION VISCOSITY

AMINE	VISCOSITY (cps) at 77°F.
DIPA	3.9
MIPA	8.0
MEA	12.0
TEA	230.0

Mineral oil and water dispersions in 1:1 fatty acid-alkanolamine mole ratio of components. Table 1 at left uses TEA as the amine, Table 2 at right uses oleic acid. Both systems contain approximately 80 parts water, 15 parts oil, and 7.5 parts total emulsifier.

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UNIQUE THICKENER HAS SURFACTANT PROPERTIES, EXEMPT FDA STATUS

Methocel®, Dow methylcellulose, is an outstanding example of a synthetic methylcellulose gum that excels natural gums as a thickener and has valuable side properties as well. In addition to thickening, Methocel products are used as emulsifiers, emulsion stabilizers, suspending agents, and binders.

Methocel compounds are also unique in the class of gum compounds for their *surfactant* properties. Lowering the surface tension of water, Methocel is classed as a moderately active wetting agent. In many formulations Methocel acts as both thickener and surfactant.

ORGANIC COMPATIBILITY. One of the Methocel products—60 HG—differs from other synthetic or natural gums because of its solubility in both water and in organic solvents. High organic compatibility suggests its use for emulsifying a variety of aromatic and other organic materials. Another—Methocel 70 HG—has provided the answer to some of the problems encountered in the preparation of straight-chain hydrocarbon emulsions.

APPROVED FOR FOOD USE. Methocel products have been used as food additives for many years. Methocel MC, U.S.P., is generally recognized as safe for use in foods (*Federal Register,* 881, February 2, 1960). A food additive petition has been filed (No. 72) covering the use of the Methocel HG products in foods (*Federal Register,* 1690, February 26, 1960). Current use of the Methocel HG products is permitted under an extension of the effective date of the statute to March 6, 1961 (*Federal Register,* 1071, February 6, 1960).

LATEX THICKENER. Methocel products work exceptionally well with latexes as viscosity control agents, stabilizers, and plasticizer dispersants. Other uses for Methocel with latex are for adhesives, paper and textile coatings, dipped rubber goods, and paint.

NEW GRANULAR FORM. A free-flowing, dust-free granular form of Methocel permits dispersion in cold water without lumping. It is especially useful in latex paint manufacture.

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Midland, Michigan

The Origin of Cities

The agricultural revolution ultimately made it possible for men to congregate in large communities, and to take up specialized tasks. The first cities almost certainly arose in Mesopotamia

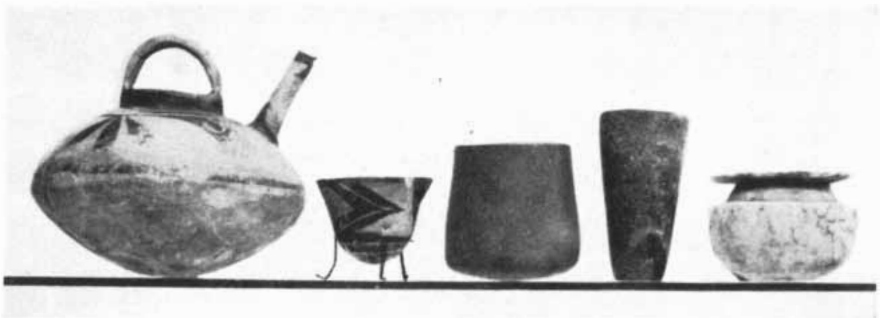
by Robert M. Adams

The rise of cities, the second great "revolution" in human culture, was pre-eminently a social process, an expression more of changes in man's interaction with his fellows than in his interaction with his environment. For this reason it marks not only a turning but also a branching point in the history of the human species.

Earlier steps are closely identified with an increasing breadth or intensity in the exploitation of the environment. Their distinguishing features are new tools and techniques and the discovery of new and more dependable resources for subsistence. Even in so advanced an achievement as the invention of agriculture, much of the variation from region to region was simply a reflection of local differences in subsistence potential.

In contrast the urban revolution was

MAP OF NIPPUR on a clay tablet dates from about 1500 B.C. Two lines at far left trace the course of Euphrates River; adjacent lines show one wall of the city. Square structures at far right are temples; the two vertical lines at right center represent a canal.



EARLY GRAVE OFFERINGS from Mesopotamian tombs of about 3900 B.C. consist mainly of painted pottery such as two vessels at left. Vessels of diorite (*center and right center*) and alabaster (*far right*), found in tombs of about 3500 B.C. and later, reflect growth of trade with other regions and increasing specialization of crafts. These vessels and objects on opposite page are in the University Museum of the University of Pennsylvania.

a decisive cultural and social change that was less directly linked to changes in the exploitation of the environment. To be sure, it rested ultimately on food surpluses obtained by agricultural producers above their own requirements and somehow made available to city dwellers engaged in other activities. But its essential element was a whole series of new institutions and the vastly greater size and complexity of the social unit, rather than basic innovations in subsistence. In short, the different forms that early urban societies assumed are essentially the products of differently interacting political and economic—human—forces. And the interpretive skills required to understand them are correspondingly rooted more in the social sciences and humanities than in the natural sciences.

Even the term urban needs qualification. Many of the qualities we think of as civilized have been attained by societies that failed to organize cities. At least some Egyptologists believe that civilization advanced for almost 2,000 years under the Pharaohs before true cities appeared in Egypt. The period was marked by the development of monumental public works, a formal state superstructure, written records and the beginnings of exact science. In the New World, too, scholars are still searching the jungles around Maya temple centers in Guatemala and Yucatán for recognizably urban agglomerations of dwellings. For all its temple architecture and high art, and the intellectual achievement represented by its hieroglyphic writing and accurate long-count calendar, classic Maya civilization apparently was not based on the city.

These facts do not detract from the fundamental importance of the urban revolution, but underline its complex character. Every high civilization other than possibly the Mayan did ultimately produce cities. And in most civilizations urbanization began early.

There is little doubt that this was the case for the oldest civilization and the earliest cities: those of ancient Mesopotamia. The story of their development, which we will sketch here, is still a very tentative one. In large part the uncertainties are due to the state of the archeological record, which is as yet both scanty and unrepresentative. The archeologist's preoccupation with early temple-furnishings and architecture, for example, has probably exaggerated their importance, and has certainly given us little information about contemporary secular life in neighboring precincts of the same towns.

Eventually written records help overcome these deficiencies. However, 500 or more years elapsed between the onset of the first trends toward urbanism and the earliest known examples of cuneiform script. And then for the succeeding 700 or 800 years the available texts are laconic, few in number and poorly understood. To a degree, they can be supplemented by cautious inferences drawn from later documents. But the earliest chapters rest primarily on archeological data.

Let us pick up the narrative where Robert J. Braidwood left it in the preceding article, with the emergence of a fully agricultural people, many of them grouped together in villages of perhaps 200 to 500 individuals. Until almost the end of our own story, dating finds little corroboration in written records. Moreover, few dates based on the decay of radioactive carbon are yet available in Mesopotamia for this crucial period. But by 5500 B.C., or even earlier, it appears that the village-farming community had fully matured in southwestern Asia. As a way of life it then stabilized internally for 1,500 years or more, although it continued to spread downward from the hills and piedmont where it had first crystallized in the great river valleys.

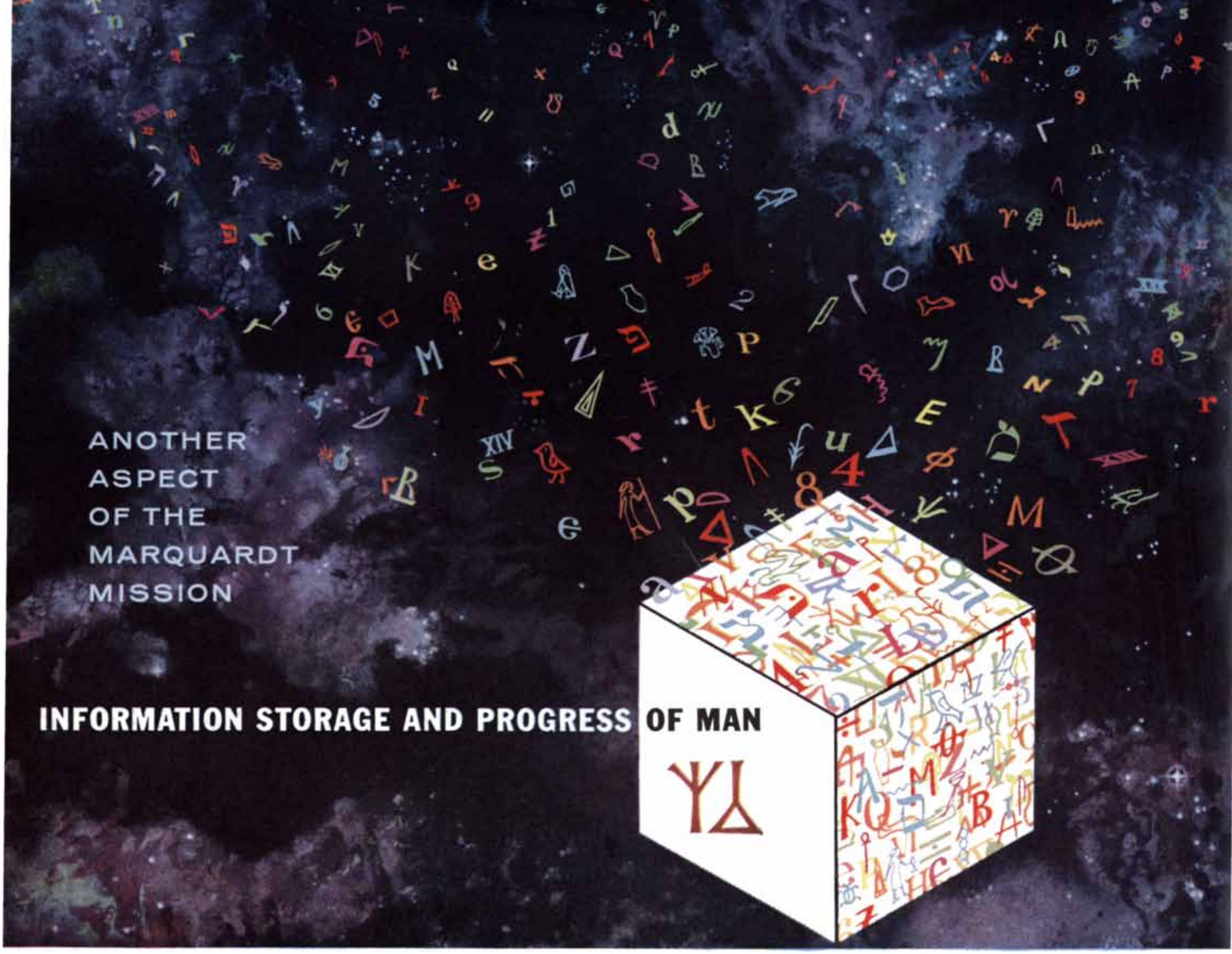
Then came a sharp increase in tempo. In the next 1,000 years some of the small agricultural communities on the alluvial plain between the Tigris and Euphrates rivers not only increased greatly in size, but changed decisively in structure. They culminated in the Sumerian city-state with tens of thousands of inhabitants, elaborate religious, political and military establishments, stratified social classes, advanced technology and widely extended trading contacts [see "The Sumerians," by Samuel Noah Kramer; SCIENTIFIC AMERICAN, October, 1957]. The river-valley agriculture on which the early Mesopotamian cities were established differed considerably from that of the uplands where domestication had begun. Wheat and barley remained the staple crops, but they were supplemented by dates. The date palm yielded not only prodigious and dependable supplies of fruit but also wood. Marshes and estuaries teemed with fish, and their reeds provided another building material. There was almost no stone, however; before the establishment of trade with surrounding areas, hard-fired clay served for such necessary agricultural tools as sickles.

The domestic animals—sheep, goats, donkeys, cattle and pigs by the time of the first textual evidence—may have differed little from those known earlier in the foothills and northern plains. But they were harder to keep, particularly the cattle and the donkeys which were needed as draft animals for plowing. During the hot summers all vegetation withered except for narrow strips along the watercourses. Fodder had to be cultivated and distributed, and pastureland was at a premium. These problems of management may help explain why the herds rapidly became a responsibility of people associated with the temples. And control of the herds in turn may have provided the stimulus that led temple officials frequently to assume broader control over the economy and agriculture.

Most important, agriculture in the alluvium depended on irrigation, which had not been necessary in the uplands. For a long time the farmers made do with small-scale systems, involving breaches in the natural embankments of the streams and uncontrolled local flooding. The beginnings of large-scale canal networks seem clearly later than the advent of fully established cities.

In short, the immediately pre-urban society of southern Mesopotamia con-

ROYAL GRAVE OFFERINGS from later tombs at Ur indicate the concentration of wealth that accompanied the emergence of a kingly class. Dated at about 2500 B.C., the objects include large gold earrings (*top*); a headdress with gold leaves; beads of gold, lapis and carnelian; gold rings; a gold leaf; a hairpin of gold and lapis; an ornament with a gold pendant; an adz head of electrum.



If the technological history of man's accomplishments were divided into a twenty-four hour day, the accomplishments of the twenty-fourth hour would vastly outweigh the sum total of the first twenty-three. This surge of progress has resulted in part from man's ability to permanently record and use information relating to his experience.

The writing of human experience — the first permanent information storage system — began only 10,000 years ago. The pages of history written since, would require a storage area larger than the Empire State Building to contain them. Thus man's ability to chronicle facts has far exceeded his capability to store them for easy reference.

Now scientists in the Pomona Division and ASTRO, Marquardt's division for research into the space age, are developing a multi-channel information storage system with an order of magnitude superior to any known storage method. RESULT: all information recorded during the first 100 centuries of civilization's history may be stored in a 6 foot cube.

The future, viewed in the perspective of this new memory potential, offers man the opportunity for an even greater rate of progress — wherein it is possible to envision the achievements of the last minute of the exemplary 24th hour exceeding the sum-total of the first 1,439 minutes.

New information storage concepts typify but one aspect of The Marquardt Mission.

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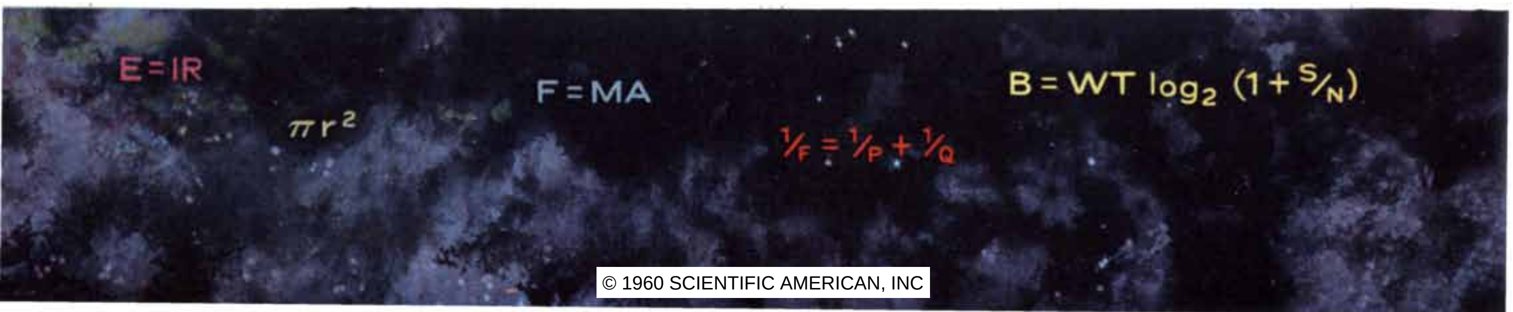
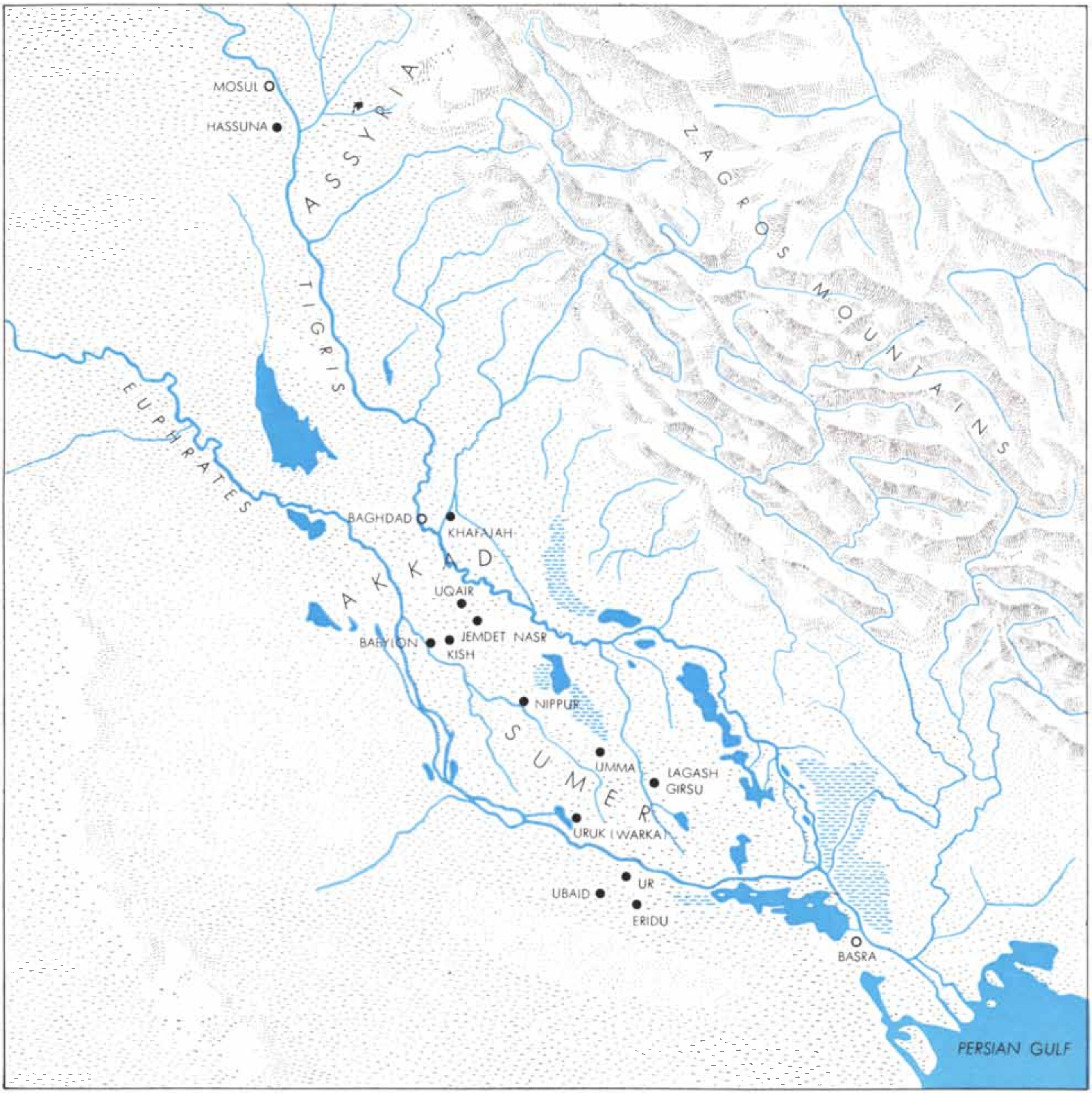


sisted of small communities scattered along natural watercourses. Flocks had to forage widely, but cultivation was confined to narrow enclaves of irrigated plots along swamp margins and stream banks. In general the swamps and rivers provided an important part of the raw materials and diet.

Where in this pattern were the inducements, perhaps even preconditions, for urbanization that explain the precocity of the Mesopotamian achievement? First, there was the productivity of irrigation agriculture. In spite of chronic water-shortage during the earlier part of the growing season and periodic floods around the time of the harvest, in spite of a debilitating summer climate and the ever present danger of salinity in flooded or over-irrigated fields, farming yielded a clear and dependable surplus of food.

Second, the very practice of irrigation must have helped induce the growth of cities. It is sometimes maintained that the inducement lay in a need for centralized control over the building and maintaining of elaborate irrigation systems, but this does not seem to have been the case. As we have seen, such systems came after the cities themselves. However, by engendering inequalities in access to productive land, irrigation contributed to the formation of a stratified society. And by furnishing a reason for border disputes between neighboring communities, it surely promoted a warlike atmosphere that drew people together in offensive and defensive concentrations.

Finally, the complexity of subsistence pursuits on the flood plains may have indirectly aided the movement toward cities. Institutions were needed to medi-



ANCIENT CITIES of Mesopotamia (*black dots*) were located mainly along Tigris and Euphrates rivers and their tributaries. In ancient times these rivers followed different courses from those shown on this modern map. Modern cities are shown as open dots.

CITY OF ERBIL in northern Iraq is built on the site of ancient city of Arbela. This aerial view suggests the character and appearance of Mesopotamian cities of thousands of

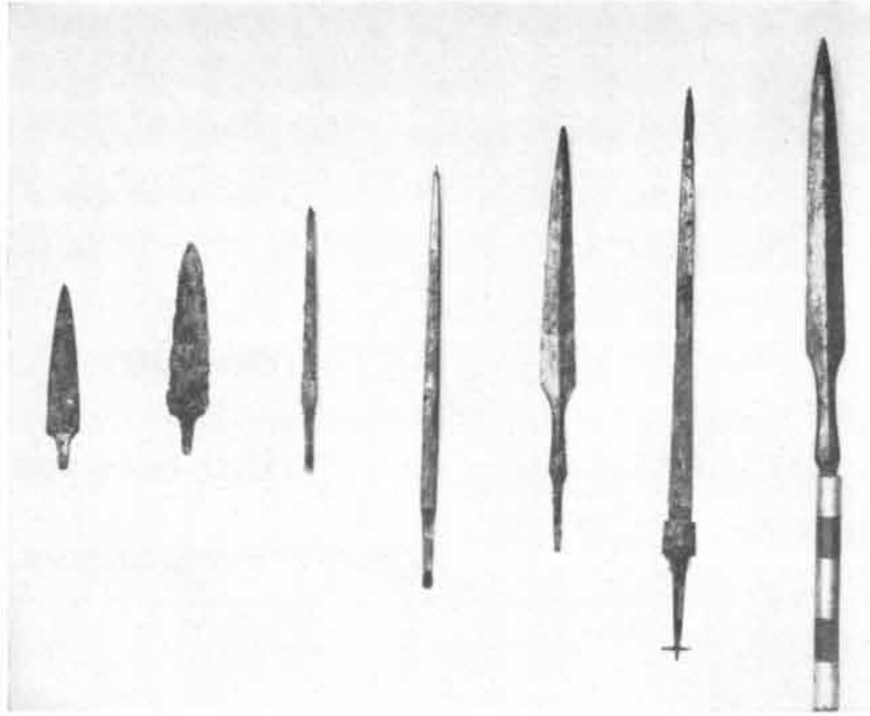
ate between herdsman and cultivator; between fisherman and sailor; between plowmaker and plowman. Whether through a system of rationing, palace largesse or a market that would be recognizable to us, the city provided a logical and necessary setting for storage, exchange and redistribution. Not surprisingly, one of the recurrent themes in early myths is a rather didactic demonstration that the welfare of the city goddess is founded upon the harmonious interdependence of the shepherd and the farmer.

In any case the gathering forces for urbanization first become evident around 4000 B.C. Which of them furnished the initial impetus is impossible to say, if indeed any single factor was responsible. We do not even know as yet whether the onset of the process was signaled by a growth in the size of settlements. And of course mere increase in size would not necessarily imply technological or economic advance beyond the level of the village-farming community. In our own time we have seen primitive agricultural peoples, such as the Yoruba of western Nigeria, who maintained sizable cities that were in fact little more than overgrown village-farming settlements. They were largely self-sustaining because most of the productive inhabitants were full-time farmers.

years ago, with streets and houses closely packed around central public buildings.

The evidence suggests that at the beginning the same was true of Mesopotamian urbanization: immediate economic change was not its central characteristic. As we shall see shortly, the first clear-cut trend to appear in the archeological record is the rise of temples. Conceivably new patterns of thought and social organization crystallizing within the temples served as the primary force in bringing people together and setting the process in motion.

Whatever the initial stimulus to growth and reorganization, the process itself clearly involved the interaction of many different factors. Certainly the institutions of the city evolved in different



SPEARHEADS of copper and bronze from the sites of Tepe Gawra, Tell Billa and Ur date back to the third millennium B.C. Growth of cities was closely linked to rise of warfare.

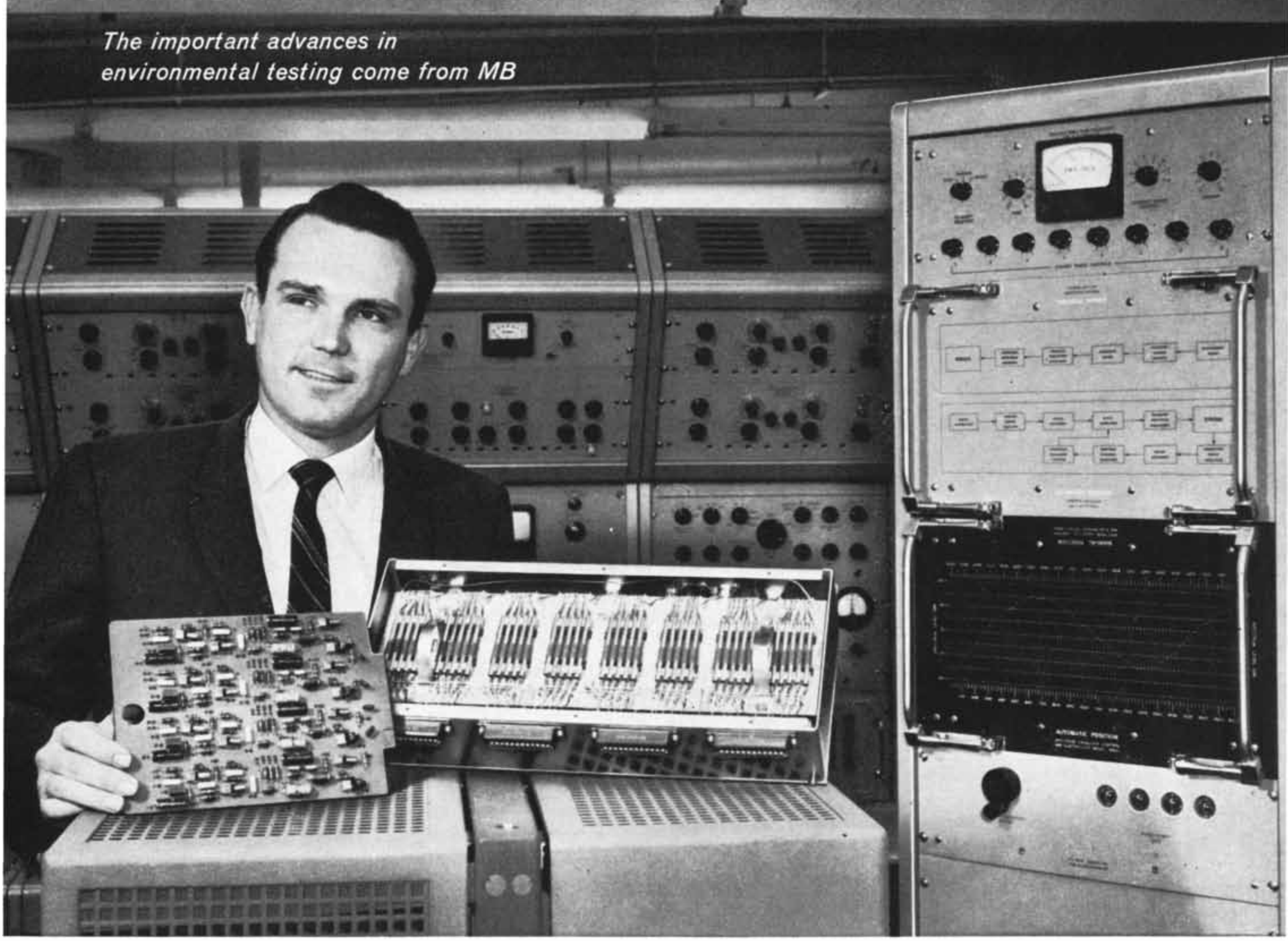
directions and at different rates, rather than as a smoothly emerging totality. Considering the present fragmentary state of knowledge, it is more reasonable here to follow some of these trends individually rather than to speculate from the shreds (or, rather, sherds!) and patches of data about how the complete organizational pattern developed.

Four archeological periods can be distinguished in the tentative chronology of the rise of the Mesopotamian city-state. The earliest is the Ubaid, named for the first site where remains of this period were uncovered [*see map on page 157*]. At little more than a guess, it may have lasted for a century or two past 4000 B.C., giving way to the relatively brief Warka period. Following this the first written records appeared during the Protoliterate period, which spanned the remainder of the fourth millennium. The final part of our story is the Early Dynastic period, which saw the full flowering of independent city-states between about 3000 and 2500 B.C.

Of all the currents that run through the whole interval, we know most about religious institutions. Small shrines existed in the early villages of the northern plains and were included in the cultural inventory of the earliest known agriculturalists in the alluvium. Before the end of the Ubaid period the free-standing shrine had lost its original fluidity of plan and adopted architectural features that afterward permanently characterized Mesopotamian temples. The development continued into the Early Dynastic period, when we see a complex of workshops and storehouses surrounding a greatly enlarged but rigidly traditional arrangement of cult chambers. No known contemporary structures were remotely comparable in size or complexity to these establishments until almost the end of the Protoliterate period.

At some point specialized priests appeared, probably the first persons released from direct subsistence labor. Their ritual activities are depicted in Protoliterate seals and stone carvings. If not immediately, then quite early, the priests also assumed the role of economic administrators, as attested by ration or wage lists found in temple premises among the earliest known examples of writing. The priestly hierarchies continued to supervise a multitude of economic as well as ritual activities into (and beyond) the Early Dynastic period, although by then more explicitly political forms of organization had perhaps become dominant. For a long time, however, temples seem to have been the largest and most complex institutions that existed in the communities growing up around them.

The beginnings of dynastic political regimes are much harder to trace. Monumental palaces, rivaling the temples in size, appear in the Early Dynastic



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period, but not earlier. The term for "king" has not yet been found in Protoliterate texts. Even so-called royal tombs apparently began only in the Early Dynastic period.

Lacking contemporary historical or archeological evidence, we must seek the origins of dynastic institutions primarily in later written versions of traditional myths. Thorkild Jacobsen of the University of Chicago has argued persuasively that Sumerian myths describing the world of the gods reflect political institutions as they existed in human society just prior to the rise of dynastic authority. If so, they show that political authority in the Protoliterate period rested in an assembly of the adult male members of the community. Convoked only to meet sporadic external threat, the assembly's task was merely to select a short-term war leader.

Eventually, as the myths themselves suggest, successful war leaders were retained even in times of peace. Herein lies the apparent origin of kingship. At times springing up outside the priestly corporations, at times coming from them, new leaders emerged who were preoccupied with, and committed to, both defensive and offensive warfare against neighboring city-states.

The traditional concerns of the temples were not immediately affected by the new political leadership. Palace officials acquired great landed estates of their own, but the palace itself was occupied chiefly with such novel activities as raising and supplying its army, maintaining a large retinue of servants and entertainers and constructing a defensive wall around the city.

These undertakings took a heavy toll of the resources of the young city-states, perhaps too heavy to exact by the old "democratic" processes. Hence it is not surprising that as permanent, hereditary royal authority became established, the position of the assembly declined. In the famous epic of Gilgamesh, an Early Dynastic king of Uruk, the story opens with the protests of the citizenry over their forced labor on the city walls. Another episode shows Gilgamesh manipulating the assembly, obviously no longer depending on its approval for his power. Rooted in war, the institution of kingship intensified a pattern of predatory expansionism and shifting military rivalries. The early Mesopotamian king could trace his origin to the need for military leadership. But the increasingly militaristic flavor of the Early Dynastic period also can be traced at least in part to the interests and activities of kings and their retinues as they proceeded to consolidate their power.

As society shifted its central focus from temple to palace it also separated into classes. Archeologically, the process can best be followed through the increasing differentiation in grave offerings in successively later cemeteries. Graves of the Ubaid period, at the time when monumental temples were first appearing, hold little more than a variable number of pottery vessels. Those in the cemetery at Ur, dating from the latter part of the Early Dynastic period, show a great disparity in the wealth they contain. A small proportion, the royal tombs (not all of whose principal occupants may have belonged to royal families), are richly furnished with beautifully wrought weapons, ornaments and utensils of gold and lapis lazuli. A larger number contain a few copper vessels or an occasional bead of precious metal, but the majority have only pottery vessels or even nothing at all. Both texts and archeological evidence indicate that copper and bronze agricultural tools were beyond the reach of the ordinary

ROYAL WAR-CHARIOT carved on limestone plaque from city of Ur reflects increasing concern of Mesopotamian cities about methods of warfare in middle of third millennium B.C.

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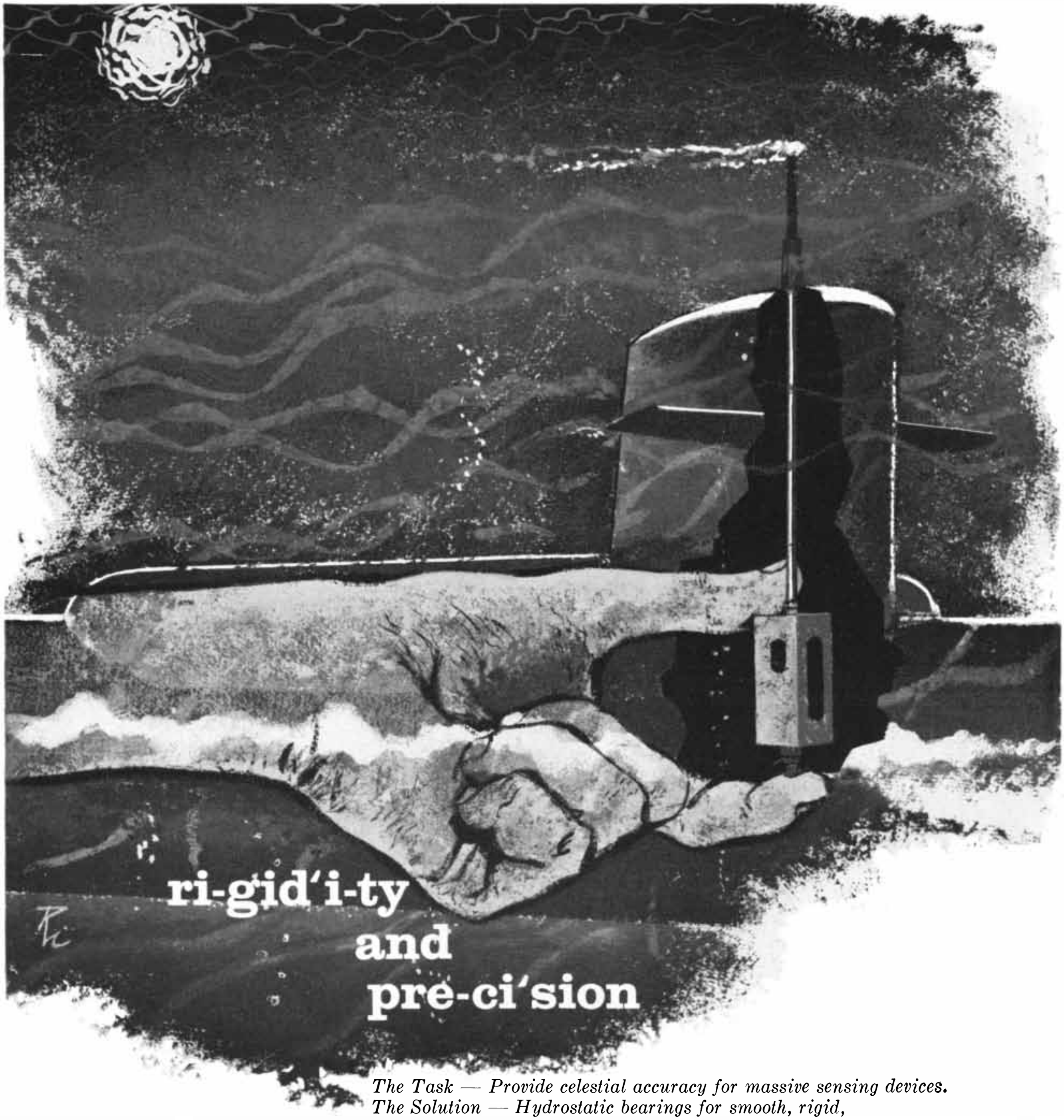

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RELIGIONS of ancient Mesopotamia were dominated by the idea that man was fashioned to serve the gods. Here a worshipper followed by figure with pail brings a goat as an offering to goddess seated at right. A divine attendant kneels before her. This impression and one on next page were made from stone cylinder-seals of Akkadian period (about 2400 B.C.).

peasant until after the Early Dynastic period, while graves of the well-to-do show "conspicuous consumption" of copper in the form of superfluous stands for pottery vessels even from the beginning of the period.

Early Dynastic texts likewise record social and economic stratification. Records from the main archive of the Baba Temple in Girsu, for example, show substantial differences in the allotments from that temple's lands to its parishioners. Other texts describe the sale of houseplots or fields, often to form great estates held by palace officials and worked by communities of dependent clients who may originally have owned the land. Still others record the sale of slaves, and the rations allotted to slaves producing textiles under the supervision of temple officials. As a group, however, slaves constituted only a small minority of the population until long after the Early Dynastic period.

Turning to the development of technology, we find a major creative burst in early Protoliterate times, involving very rapid stylistic and technical advance in the manufacture of seals, statuary and ornate vessels of carved stone, cast copper or precious metals. But the number of craft specialists apparently was very small, and the bulk of their products seems to have been intended only for cult purposes. In contrast the Early Dynastic period saw a great increase in production of nonagricultural commodities, and almost certainly a corresponding increase in the proportion of the population that was freed from the tasks of primary subsistence to pursue their craft on a full-time basis. Both stylistically and technologically, however, this expansion was rooted in the accomplishments of the previous period and produced few innovations of its own.

Production was largely stimulated by three new classes of demand. First, the burgeoning military establishment of the palace required armaments, including not only metal weapons and armor but also more elaborate equipment such as chariots. Second, a considerable volume of luxury goods was commissioned for the palace retinue. And third, a moderate private demand for these goods seems to have developed also. The mass production of pottery, the prevalence of such articles as cylinder seals and metal utensils, the existence of a few vendors' stalls and the hoards of objects in some of the more substantial houses all imply at least a small middle class. Most of these commodities, it is clear, were fabricated in the major Mesopotamian towns from raw materials brought from considerable distance. Copper, for example, came from Oman and the Anatolian plateau, more than 1,000 miles from the Sumerian cities. The need for imports stimulated the manufacture of such articles as textiles, which could be offered in exchange, and also motivated the expansion of territorial control by conquest.

Some authorities have considered that technological advance, which they usually equate with the development of metallurgy, was a major stimulant or even a precondition of urban growth. Yet, in southern Mesopotamia at least, the major quantitative expansion of metallurgy, and of specialized crafts in general, came only after dynastic city-states were well advanced. While the spread of technology probably contributed further to the development of militarism and social stratification, it was less a cause than a consequence of city growth. The same situation is found in New World civilizations. Particularly in aboriginal Middle America the technological level remained very nearly static before and after the urban period.

Finally we come to the general forms of the developing cities, perhaps the most obscure aspect of the whole process of urbanization. Unhappily even Early Dynastic accounts do not oblige us with extensive descriptions of the towns where they were written, nor even with useful estimates of population. Contemporary maps also are unknown; if they were made, they still elude us. References to towns in the myths and epics are at best vague and allegorical. Ultimately archeological studies can supply most of these deficiencies, but at present we have little to go on.

The farming villages of the pre-urban era covered at most a few acres. Whether the villages scattered over the alluvial plain in Ubaid times were much different from the earlier ones in the north is unclear; certainly most were no larger, but the superficial appearance of one largely unexcavated site indicates that they may have been more densely built up and more formally laid out along a regular grid of streets or lanes. By the end of the Ubaid period the temples had begun to expand; a continuation of this trend is about all that the remains of Warka and early Protoliterate periods can tell us thus far. Substantial growth seems to have begun toward the end of the Protoliterate period and to have continued through several centuries of the Early Dynastic. During this time the first battlemented ring-walls were built around at least the larger towns.

A few Early Dynastic sites have been excavated sufficiently to give a fairly full picture of their general layout. Radiating out from the massive public buildings of these cities, toward the outer gates, were streets, unpaved and dusty, but straight and wide enough for the passage of solid-wheeled carts or chariots. Along the streets lay the residences of the well-to-do citizenry, usually arranged around spacious courts and sometimes provided with latrines draining into sewage conduits below the streets. The houses of the city's poorer inhabitants were located behind or between the large multiroomed dwellings. They were approached by tortuous, narrow alleys, were more haphazard in plan, were less well built and very much smaller. Mercantile activities were probably concentrated along the quays of the adjoining river or at the city gates. The marketplace or bazaar devoted to private commerce had not yet appeared.

Around every important urban center rose the massive fortifications that guarded the city against nomadic raids and the usually more formidable campaigns of neighboring rulers. Outside the walls clustered sheepfolds and irrigated tracts, interspersed with subsidiary villages and ultimately disappearing into the desert. And in the desert dwelt only the nomad, an object of mixed fear and scorn to the sophisticated court poet. By the latter part of the Early Dynastic period several of the important capitals of lower Mesopotamia included more than 250 acres within their fortifications. The city of Uruk extended over 1,100 acres and contained possibly 50,000 people.

For these later cities there are written records from which the make-up of the population can be estimated. The overwhelming majority of the able-bodied adults still were engaged in primary

GILGAMESH, early Mesopotamian king and hero of legend, may be figure attacking water buffalo (*right center*). Figure stabbing lion may be his companion, the bull-man Enkidu.

agricultural production on their own holdings, on allotments of land received from the temples or as dependent retainers on large estates. But many who were engaged in subsistence agriculture also had other roles. One temple archive, for example, records that 90 herdsmen, 80 soldier-laborers, 100 fishermen, 125 sailors, pilots and oarsmen, 25 scribes, 20 or 25 craftsmen (carpenters, smiths, potters, leather-workers, stonecutters, and mat- or basket-weavers) and probably 250 to 300 slaves were numbered among its parish of around 1,200 persons. In addition to providing for its own subsistence and engaging in a variety of specialized pursuits, most of this group was expected to serve in the army in time of crisis.

Earlier figures can only be guessed at from such data as the size of temple establishments and the quantity of craft-produced articles. Toward the end of the Protoliterate period probably less than a fifth of the labor force was substantially occupied with economic activities outside of subsistence pursuits; in Ubaid times a likely figure is 5 per cent.

It is not easy to say at what stage in the whole progression the word "city" becomes applicable. By any standard Uruk and its contemporaries were cities. Yet they still lacked some of the urban characteristics of later eras. In particular, the development of municipal politics, of a self-conscious corporate body with at least partially autonomous, secular institutions for its own administration, was not consummated until classical times.

Many of the currents we have traced must have flowed repeatedly in urban civilizations. But not necessarily all of them. The growth of the Mesopotamian city was closely related to the rising tempo of warfare. For their own protection people must have tended to congregate under powerful rulers and behind strong fortifications; moreover, they may have been consciously and forcibly drawn together by the elite in the towns in order to centralize political and economic controls. On the other hand, both in aboriginal Central America and in the Indus Valley (in what is now Pakistan) great population centers grew up without comprehensive systems of fortification, and with relatively little emphasis on weapons or on warlike motifs in art.

There is not one origin of cities, but as many as there are independent cultural traditions with an urban way of life. Southern Mesopotamia merely provides the earliest example of a process that, with refinements introduced by the industrial revolution and the rise of national states, is still going on today.

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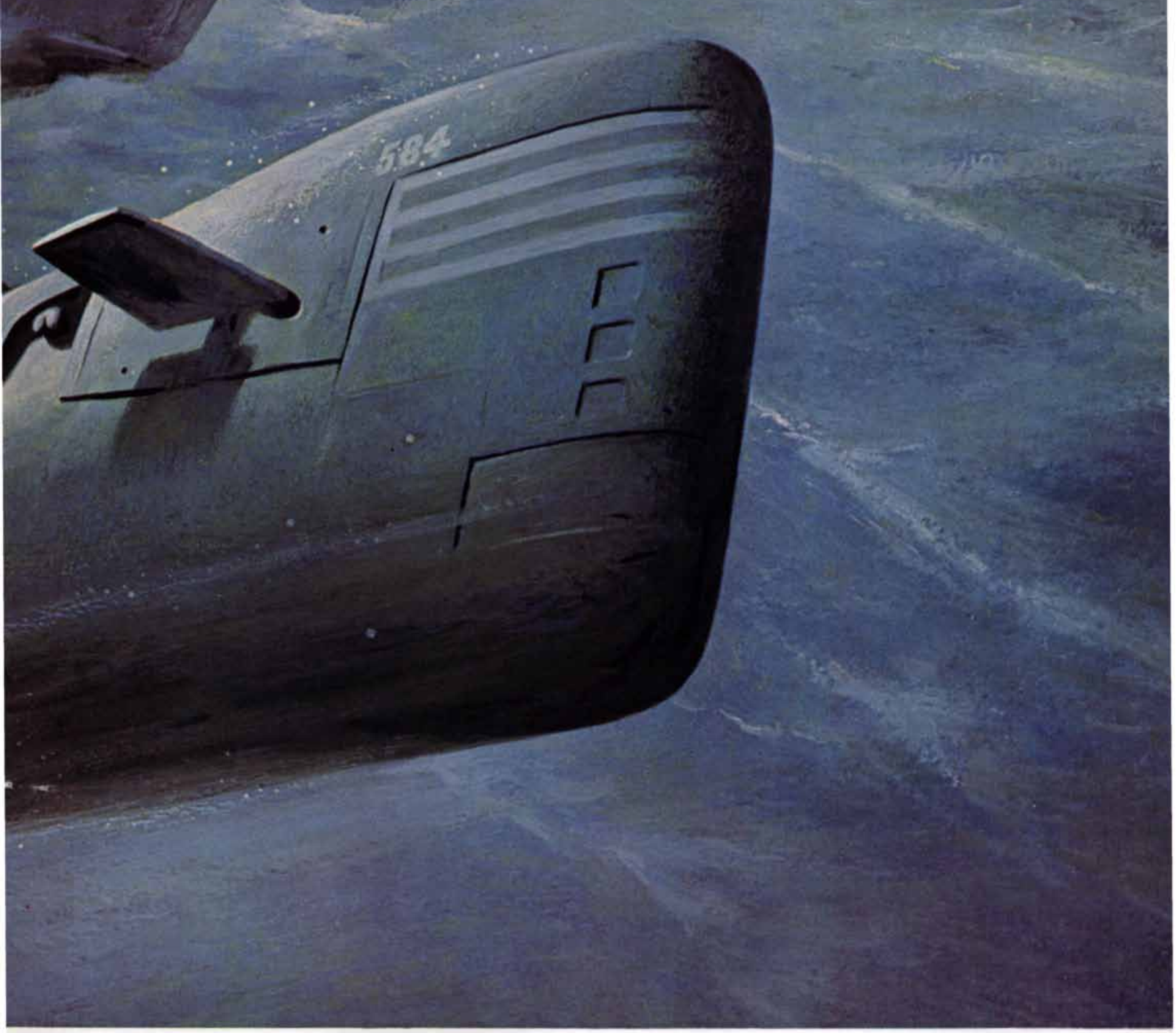
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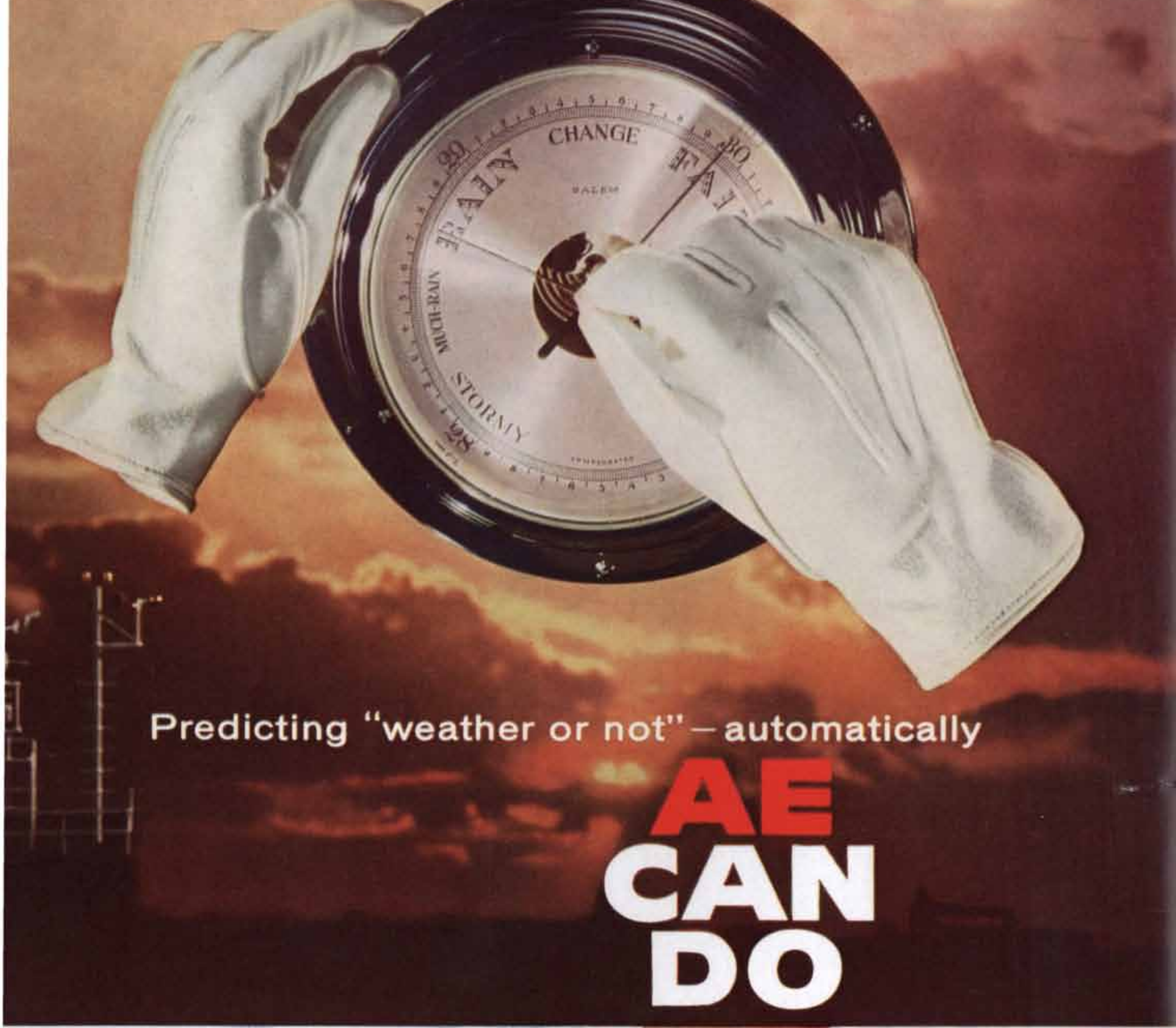

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The Scientific Revolution

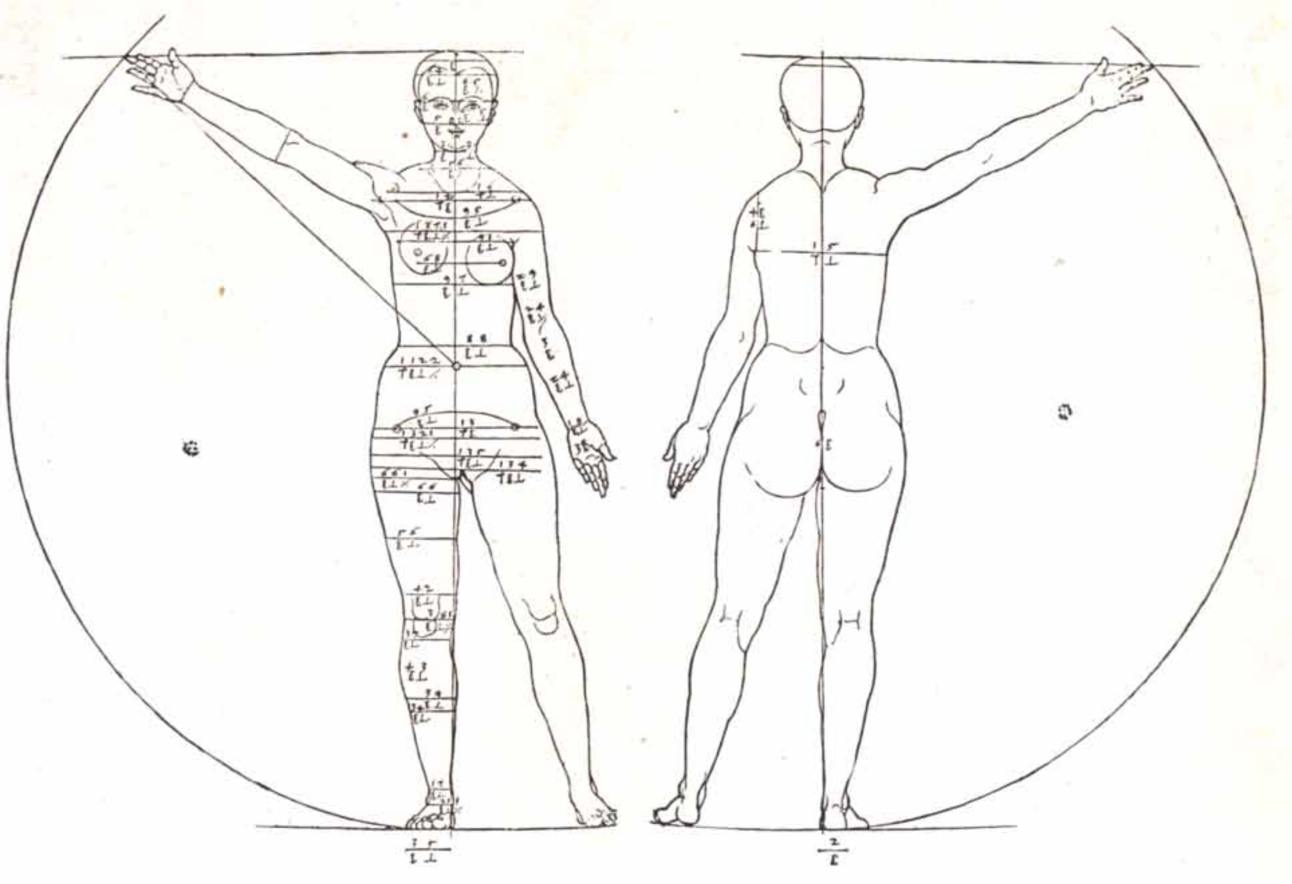
Observation of nature by Renaissance artists and craftsmen was a precursor of the new scientific outlook. This in turn accelerated technology, leading to the industrial revolution

by Herbert Butterfield

The preceding article leaves *Homo sapiens* in about 2500 B.C., after his invention of the city-state. Our story does not really get under way until some 4,000 years later. Thus, in turning to the next major revolution in man's impact on his environment, we seem to pass over almost all of recorded human history. No revolution is without its antecedents, however. Although the scientific-industrial age is a recent and original achievement of Western man, it has deep historical roots.

Western civilization is unique in its historical-mindedness as well as in its scientific character. Behind it on the one hand are the ancient Jews, whose religious literature was largely historical, who preached a God of history, and taught that history was moving to a mighty end, not merely revolving in cycles of growth and decay. On the other hand are the ancient Greeks. Their literature has provided a training in logic, a stimulus to the exercise of the critical faculties and a wonderful grounding in mathematics and the physical sciences.

In western Europe civilization had a comparatively late start. For thousands



ANATOMY, studied by Renaissance artists, was the first of the sciences to be placed on a modern footing. This drawing is from a copy of Albrecht Dürer's work *De Symmetria Partium Humanorum Corporum* in the Metropolitan Museum of Art in New York.

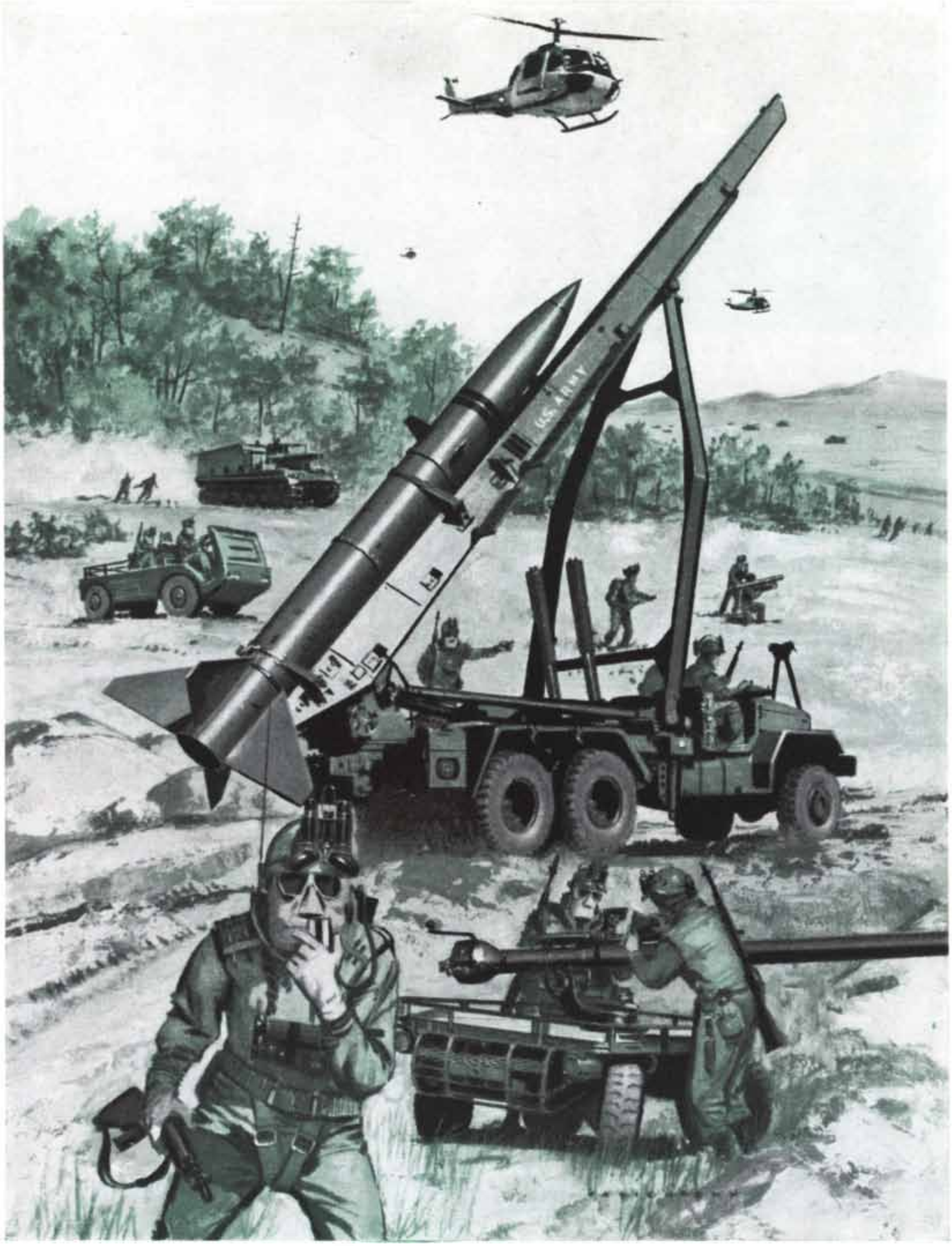
of years the lands at the eastern end of the Mediterranean had held the leadership in that whole section of the globe. It was in the West, furthermore, that the Roman Empire really collapsed, and was overrun by "barbarian invaders." Here much of the ancient culture was lost, and society reverted to comparatively primitive forms. In the meantime a high Byzantine civilization had its center in Constantinople, and a brilliant Arabian one in Baghdad. It would be interesting to know why Western man, though he started late, soon proved himself to be so much more dynamic than the peoples farther to the east.

In the formative period of a civilization religion plays a more important part than we today can easily understand. After the fall of the Roman Empire the comparatively primitive peoples in much of Europe were Christianized by conquest or through royal command; in the beginning it was a case of pagans merely changing the names of their gods. But in the succeeding centuries of the Middle Ages the Church deepened spiritual life and moral earnestness. It became the great educator, recovering ancient scholarship and acting as the patron of the arts. By the 13th century there had developed a lofty culture, very much under the presidency of religion, but a religion that nourished the inner life, stimulated heart-searchings and examinations of conscience and set an eternal value upon each individual soul. The Western tradition acquired a high doctrine of personality.

By the year 1500, when the Renaissance was at its height, the West had begun to take the command of world history. The expansion of Islam had been contained. The terrible Asian hordes, culminating in the Mongols and the Turks, that had overrun the eastern Mediterranean lands had been stopped in central Europe. One of the reasons first for survival and then for progress in the West was its consolidation into something like nation-states, a form of polity more firm and more closely knit than the sprawling Asiatic empires.

Yet the Renaissance belongs perhaps to the old (that is, the medieval) world rather than to the new; it was still greatly preoccupied with the recovery of the lost learning of ancient Greece and Rome. Its primary interest was not in scientific studies, but now, after something like a thousand years of effort, the West had recaptured virtually all it ever was to recover of ancient Greek scholarship and science. Only after this stage had been reached could the really original developments in the study of the physical universe begin. The Western mind was certainly becoming less other-worldly. In the later Middle Ages there was much thought about the nature of man as well as about the nature of God, so that a form of Christian humanism had already been developing. The Renaissance was essentially humanistic, stressing man as the image of God rather than as the doomed sinner, and it installed in western Europe the

GOTHIC CLOCK, dating from the early 16th century, was photographed at the Smithsonian Institution. Stone at bottom is the driving weight; arm at top is part of escapement. Clockworks were among earliest examples of well-ordered machines.



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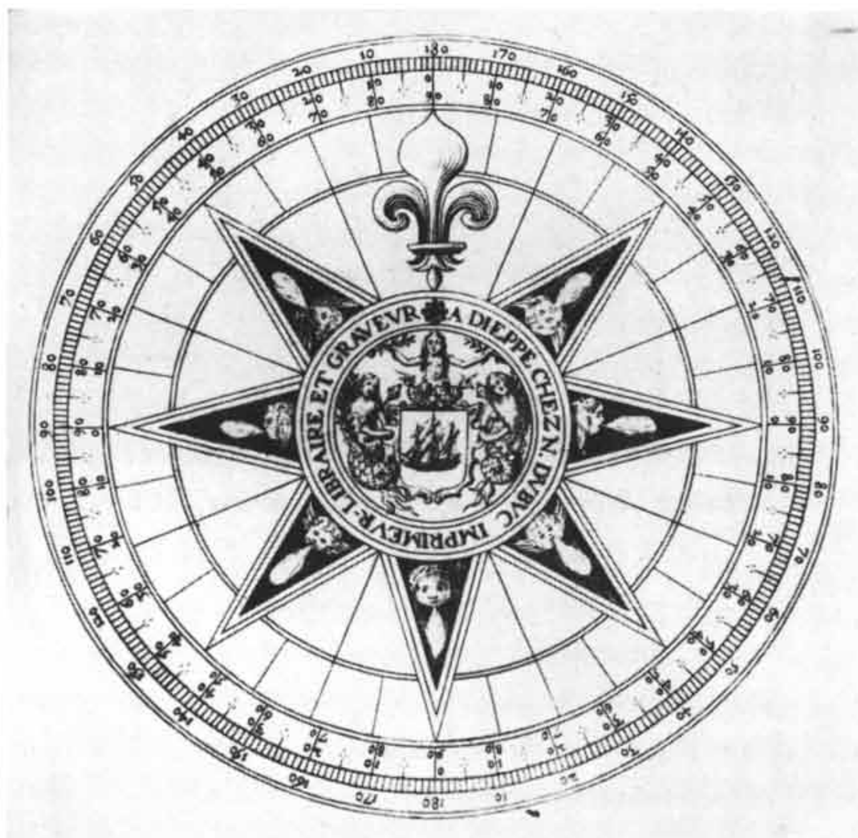
And the men of the Renaissance were still looking backward, knowing that the peak of civilization had been reached in remote antiquity, and then lost. It was easy for them to see the natural process of history as a process of decline.

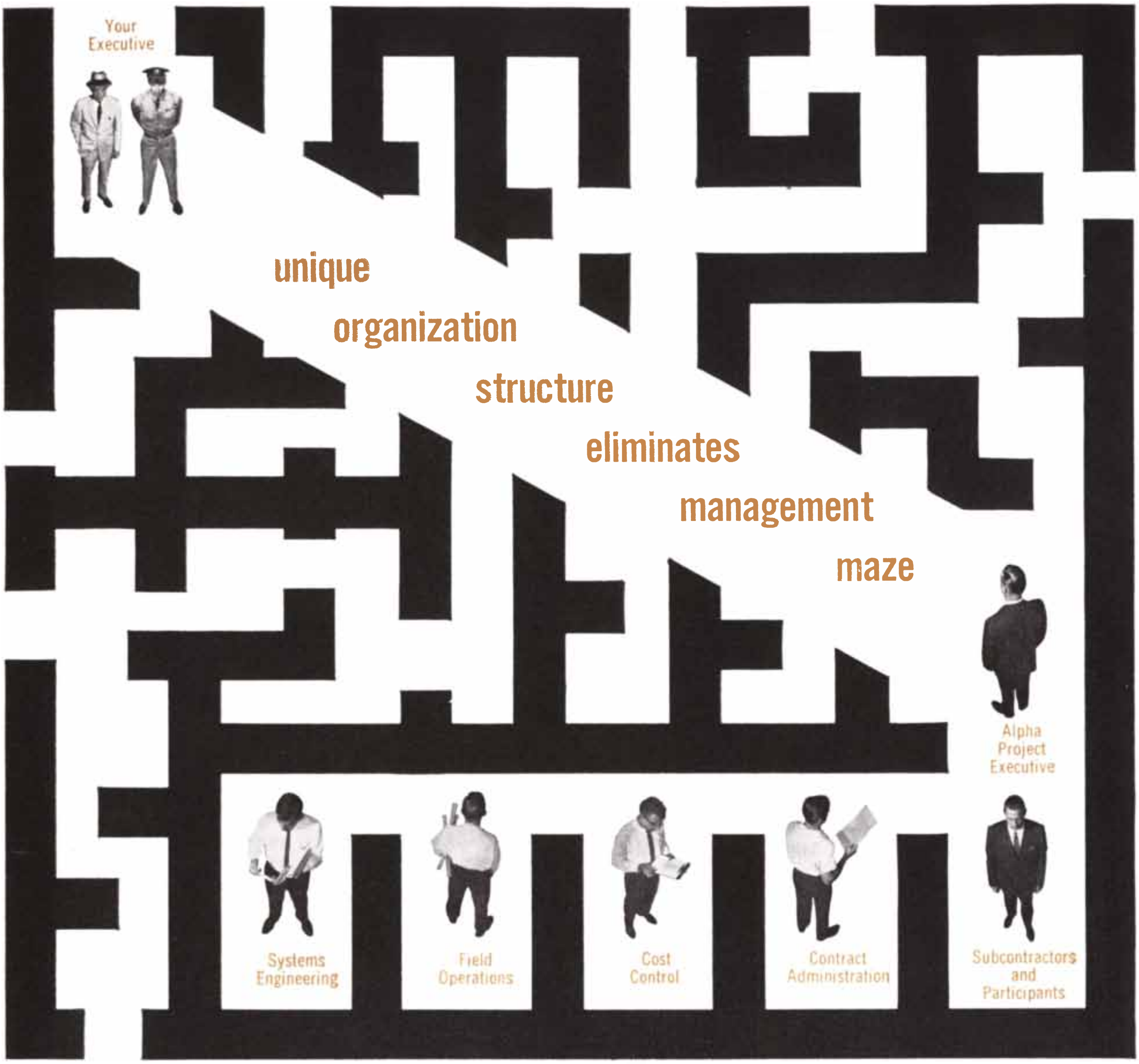
Signs of something more modern had begun to appear, but they belong chiefly to the realm of action rather than to that of thought. Theories about the universe (about the movements of the planets, for example) had still to be taken over bodily from the great teachers of the ancient world. On the other hand, in action Western man was already proving remarkably free and adventurous: in his voyages of discovery, in the development of mining and metallurgy and in the creative work of the Renaissance artists. Under these conditions scientific thought might make little progress, but technology had been able to advance. And perhaps it was the artist rather than the writer of books who, at the Renaissance, was the precursor of the modern scientist.

The artists had emancipated themselves from clerical influence to a great degree. The Florentine painters, seeking the faithful reproduction of nature, sharpened observation and prepared the way for science. The first of the sciences to be placed on a modern footing—that of anatomy—was one which the artists cultivated and which was governed by direct observation. It was the artists who even set up the cry that one must not be satisfied to learn from the ancients or to take everything from books; one must examine nature for oneself. The artists were often the engineers, the designers of fortifications, the inventors of gadgets; they were nearer to the artisan than were the scholars, and their studios often had the features of a laboratory or workshop. It is not surprising to find among them Leonardo da Vinci—a precursor of modern science, but only a precursor, in spite of his brilliance, because the modern scientific method had not yet emerged.

Records show that in the 15th century a Byzantine scholar drew the attention of his fellow-countrymen to the technological superiority of the West. He mentioned progress in machine saws, shipbuilding, textile and glass manufacture



COMPASS ROSE is reproduced from *The Art of Navigation*, published in France in 1666. The invention of the compass, which was not an achievement of classical antiquity, encouraged the men of the Renaissance to believe that they might come to excel the ancients.



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and the production of cast iron. Three other items should be added to the list: the compass, gunpowder and the printing press. Although they might not have originated in Christendom, they had not been handed down from classical antiquity. They came to be the first concrete evidence generally adduced to show that the moderns might even excel the ancients. Before 1500, artillery had assisted the consolidation of government on something like the scale of the nation-state. Printing was to speed up intellectual communication, making possible the wider spread of a more advanced kind of education and facilitating the rise of a lay intelligentsia.

In setting the stage for modern developments the economic situation is of fundamental importance. By this time a high degree of financial organization had been attained. The countryside might look much as it had done for a thousand years, but the Renaissance flourished primarily in the city-states of Italy, the Netherlands and southern Germany, where commerce and industry had made great advances. The forms of economic life were calculated to bring out individual enterprise; and in the cities the influence of priests declined—the lay intelligentsia now took the lead. There had existed greater cities and even an essentially urban civilization in ancient times. What was new was the form of the economic life, which, by the opportunities it gave to countless individuals, possessed dynamic potentialities.

It was a Western world already steeped in humanism that entered upon a great scientific and technological development. But if Western man decided now to take a hand in shaping his own destiny, he did it, as on so many other occasions, only because he had been goaded by problems that had reduced him to desperation. The decisive problems were not material ones, however. They were baffling riddles presented to the intellect.

The authority of ancient scholarship was shaken when it came to be realized that the great Greek physician Galen had been wrong in some of his observations, primarily in those on the heart. In the 16th century successive discoveries about the heart and the blood vessels were made in Padua, culminating a little later in William Harvey's demonstration in England of the circulation of the blood. The whole subject was now set on a right footing, so that a flood of further discoveries was bound to follow very quickly. Harvey's work was of the greatest importance, moreover, because it provided a pattern of what could be achieved by observation and methodical experiment.

The older kind of science came to shipwreck, however, over two problems connected with motion. Aristotle, having in mind a horse drawing a cart, had imagined that an object could not be kept moving unless something was pulling or pushing it all the time. On this view it was difficult to see why projectiles stayed in motion after they had become separated from the original propulsive force. It was conjectured that a flying arrow must be pushed along by the rush of air that its previous motion had created, but this theory had been recognized to be unsatisfactory. In the 16th century, when artillery had become familiar, the student of motion naturally tended to think of the projectile first of all. Great minds had been defeated by this problem for centuries before Galileo altered the whole approach and saw motion as

MOVABLE TYPE CAST FROM MATRICES was contribution of Johann Gutenberg to art of printing. Sample of his type, enlarged about four diameters, is from his Bible, printed about 1456. Bible in which this type appears is in Pierpont Morgan Library in New York.

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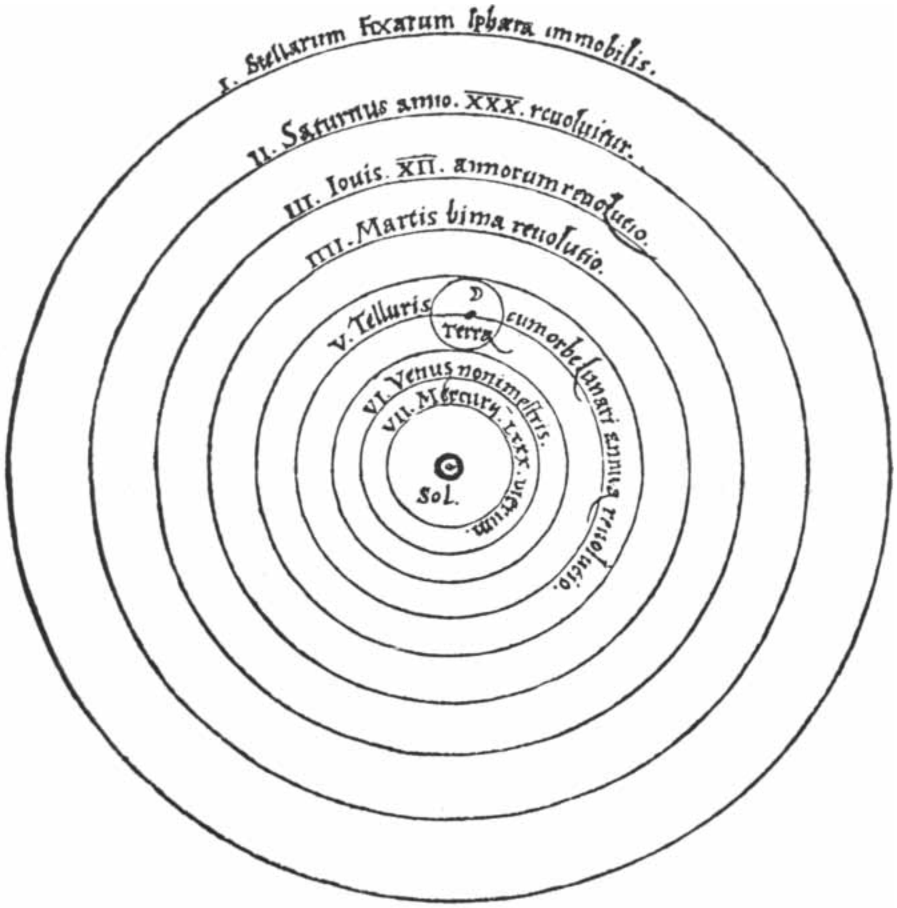

NEW COSMOLOGY OF COPERNICUS placed a fixed sun (*Sol*) at the center of the universe. The sphere of the fixed stars (*I.*) and the spheres of the six known planets revolved around the sun. Circle inscribed around the earth (*Terra*) is the lunar sphere. This woodcut appears in Copernicus's *On the Revolution of the Celestial Spheres* (1543).

something that continued until something intervened to check it.

A great astronomical problem still remained, and Copernicus did not solve it alone. Accepting the recognized data, he had shown chiefly that the neatest explanation of the old facts was the hypothesis of a rotating earth. Toward the end of the century new appearances in the sky showed that the traditional astronomy was obsolete. They demonstrated that the planets, for example, instead of being fixed to crystalline spheres that kept them in their proper courses, must be floating in empty space. There was now no doubt that comets belonged to the upper regions of the sky and cut a path through what had been regarded as the hard, though transparent, spheres. It was now not easy to see how the planets were held on a regular path. Those who followed Copernicus in the view that the earth itself moved had to face the fact that the science of physics, as it then existed, could not possibly explain how the motion was produced.

In the face of such problems it began to be realized that science as a whole needed renovation. Even in the 16th century people were beginning to examine the question of method. In this case a great historic change was willed in advance and consciously attempted. Men called for a scientific revolution before the change had occurred, and before they knew exactly what the situation demanded. Francis Bacon, who tried to establish the basis for a new scientific method, even predicted the magnitude of its possible consequences—the power that man was going to acquire over nature. It was realized, furthermore, that the authority of the ancient world, as well as that of the Middle Ages, was in question. The French philosopher René Descartes insisted that thinking should be started over again on a clean slate.

The impulse for a scientific revolution came from the pressure of high intellectual needs, but the tools of civilization helped to give the new movement its direction. In the later Middle Ages men had become more conscious of the existence of the machine, particularly


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through mechanical clocks. This may have prepared them to change the formulation of their problems. Instead of seeking the "essence" of a thing, they were now more prepared to ask, even of nature, simply: How does it work?

The student of the physical universe, like the artists before him, became more familiar with the workshop, learning manipulation from the artisan. He interested himself in problems of the practical world: artillery, pumps, the determination of longitude. Experimentation had long existed, but it now became more organized and methodical as the investigator became more conscious of what he was trying to do. In the 17th century, moreover, scientific instruments such as the telescope and the microscope came into use.

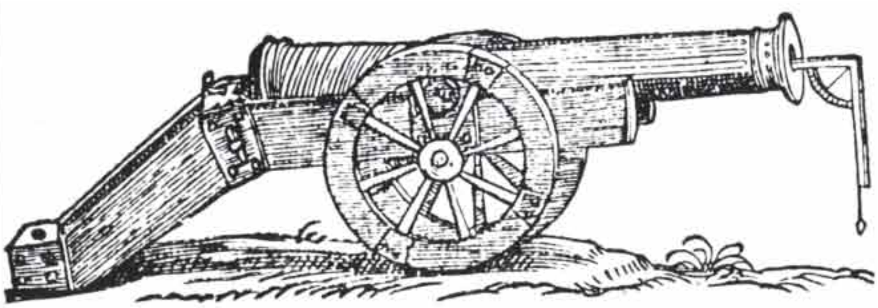
But theory mattered too. If Galileo corrected a fallacious view of motion, it was because his mind was able to change the formulation of the whole problem. At least as important as his experimentation was his mathematical attack on the problem, which illustrated the potential role of mathematics in the transformation of science.

Another momentous factor in developing the new outlook was the revival of an ancient view: that matter is composed of infinitesimally small particles. This view was now at last presented in a form that seemed consistent with Christianity (because the combinations of the particles which produced the varied world of physical things were no longer regarded as the mere product of chance), so that the atomic theory was able to acquire a wide currency. It led to a better appreciation of the intricate texture of matter, and it proved to be the source of innumerable new hypotheses. The theory seemed to open the way to a purely mechanical explanation of the universe, which should account for everything by the shape, the combination and the motion of the particles. Long before such an explanation had been achieved, men were aspiring to it. Even religious men were arguing that Creation itself would have been imperfect if God had not made a universe that was a perfectly regular machine.

The civilization that had begun its westward shift in the later Middle Ages was moving north and west. At the Renaissance Italy still held the primacy, but with the Reformation the balance shifted more definitely to the north. By the closing decades of the 17th century economic, technological and scientific progress centered on the English Channel. The leadership now belonged to England, France and the Netherlands, the countries that had been galvanized by the commerce arising from the overseas discoveries of the 15th century. And the pace was quickening. Technique was developing apace, economic life was expanding and society was moving forward generally in an exhilarating way.

The solution of the main problems of motion, particularly the motion of the earth and the heavenly bodies, and the establishment of a new notion of scientific method, took a hundred years of effort after the crisis in the later decades of the 16th century. A great number of thinkers settled single points, or made attempts that misfired. In the period after 1660 a host of workers in Paris and London were making science fashionable and bringing the scientific revolution to its culmination. Isaac Newton's *Principia* in 1687 synthesized the results of what can now be seen to have been a century of collaborative effort, and serves to signalize a new era. Newton crowned the long endeavor to see the heavenly bodies as parts of a wonderful piece of clockwork.

The achievements of ancient Greece in the field of science had now been unmistakably transcended and outmoded. The authority of both the ancient and the medieval worlds was overthrown, and Western man was fully persuaded that he must rely on his own resources in the future. Religion had come to a low



TRAJECTORIES OF PROJECTILES were calculated with aid of protractor device (*right*) invented by Niccolò Tartaglia, an Italian engineer and mathematician who died in 1577. Ballistics problems drew attention to the inadequacy of the Aristotelian ideas about motion.

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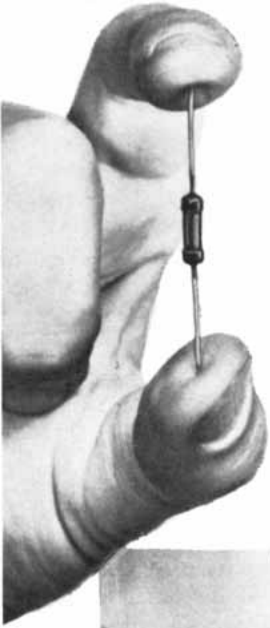
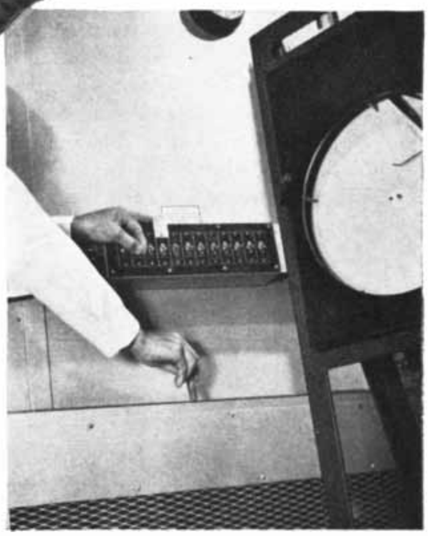


... ***frozen*** to −100° F. or fried to +1,000° F.

... ***dried out***, or soaked in humidity chambers



... ***taken aloft*** to 250,000 feet altitude

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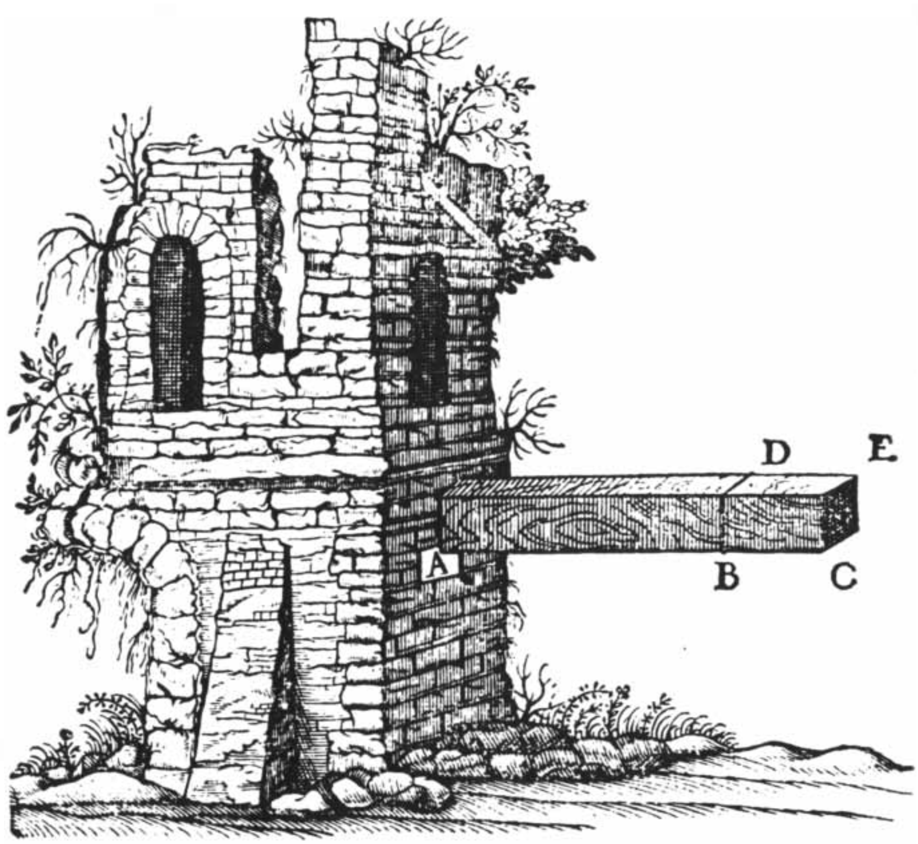
ebb after generations of fanaticism, persecution and war; now it was in a weak position for meeting the challenge of the new thought. The end of the 18th century sees in any case the decisive moment in the secularization of European society and culture. The apostles of the new movement had long been claiming that there was a scientific method which could be adapted to all realms of inquiry, including human studies—history, politics and comparative religion, for example. The foundations of what has been called the age of reason had now been laid.

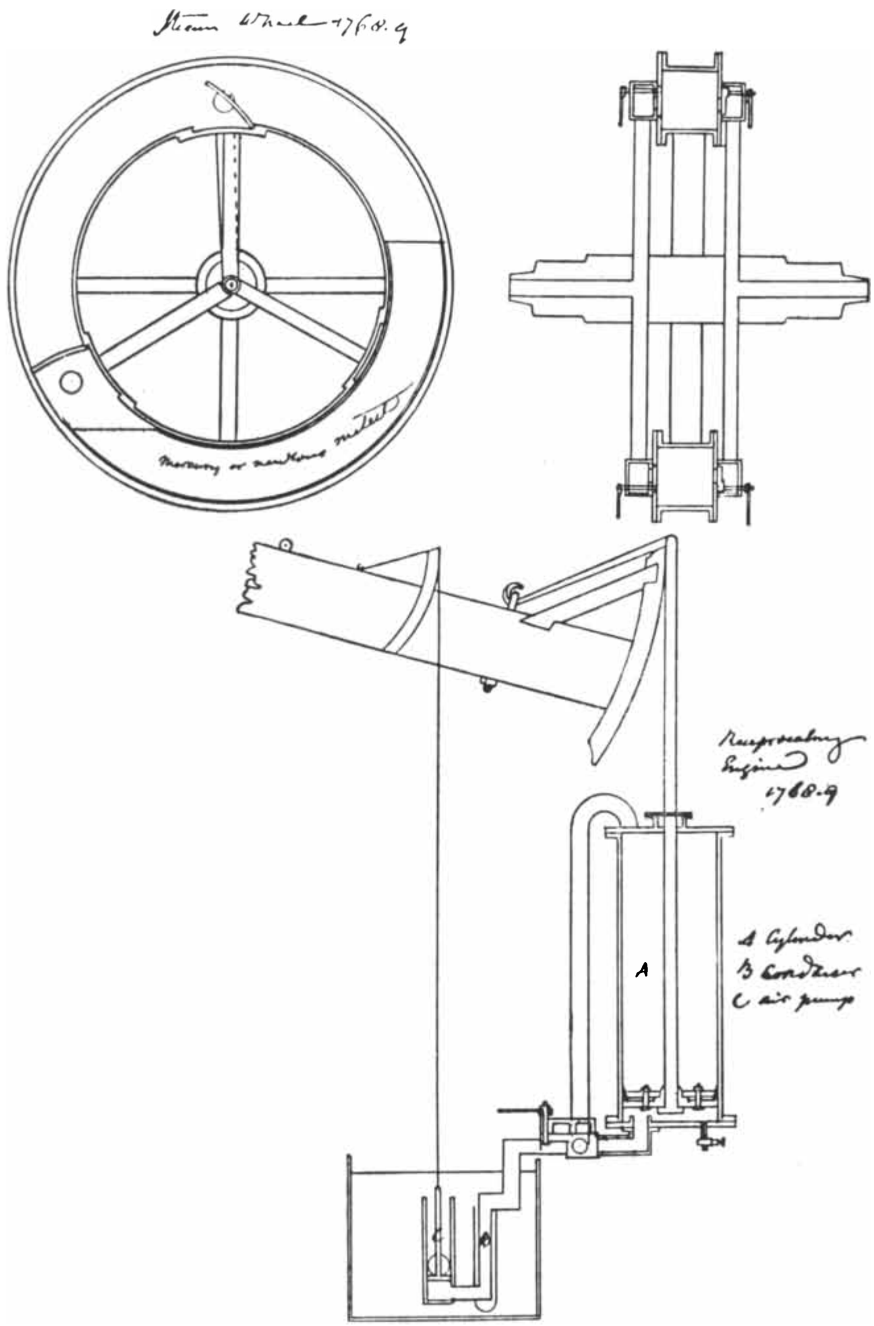
At the same time society itself was changing rapidly, and man could see it changing, see it as no longer static but dynamic. There began to emerge a different picture of the process of things in time, a picture of history as the embodiment of progress rather than of decline. The future now appeared to offer opening vistas and widening horizons. Man was coming to feel more capable of taking charge over his own destiny.

It was not merely man's tools, and not merely natural science, that had carried the story forward. The whole complex condition of society was involved, and movement was taking place on a wide front. The age of Newton sees the foundation of the Bank of England and the national debt, as well as the development of speculation that was to culminate in the South Sea Bubble. An economic order congenial to individualism meant that life was sprouting from multitudinous centers, initiatives were being taken at a thousand points and ingenuity was in constant exercise through the pressure of need or the assurance that it would have its reward. The case is illustrated in 17th-century England by the famous "projectors"—financial promoters busy devising schemes for making money. They slide easily into reformers making plans for female education or a socialistic order or a better form of government.

The whole of Western society was in movement, science and technology, industry and agriculture, all helping to carry one another along. But one of the operations of society—war—had probably influenced the general course of things more than is usually recognized. War above all had made it impossible for a king to "live of his own," enabling his subjects to develop constitutional machinery, to insist on terms in return for a grant of money. Because of wars, kings were allied with advanced cap-



STRENGTH OF A BEAM was one of the problems in which Galileo demonstrated the power of mathematical methods in science. Illustration is taken from his *Discorsi e dimostrazioni matematiche*, in which he described the "new sciences" of mechanics and motion.



DETAILS OF STEAM ENGINE are reproduced from James Watt's patent of 1769. The change from water to steam power in textile factories intensified the industrial revolution.

italistic developments from the closing centuries of the Middle Ages. The growing demands of governments in the extreme case of war tightened up the whole development of the state and produced the intensification of the idea of the state. The Bank of England and the national debt emerge during a conflict between England and France, which almost turned into a financial war and brought finance into the very structure of government. In the 17th century armies had been mounting in size, and the need for artillery and for vast numbers of uniforms had an important effect on the size of economic enterprises.

The popularity in England of the natural sciences was paralleled to a degree by an enthusiasm for antiquarian pursuits. In the later decades of the 17th century the scientific method began to affect the development of historical study. In turn, the preoccupation with the process of things in time seems to have had an influence upon scientists themselves. Perhaps the presiding scientific achievement in the next hundred years was the application of biology, geology and allied studies to the construction of a history of the physical uni-

Their problem:

To simulate nature's biological control of human environment

Names of these scientific Americans:

Drs. W. J. Oswald and C. G. Golueke, leading California scientists

■ It is a profound experience to come upon a scientific development which promises to radically change man's future. Many have had this experience upon learning of the work of these two men.

Drs. Oswald and Golueke have been able to reconvert human waste products — liquid, solid and gaseous — into a form useable in a closed-loop, biological control system. In effect, these scientists have been able to simulate this planet's biological cycle in a package of practical proportions.

Its application will provide a low-weight, reclamation process for use in space travel or, if desired, a means of converting sewage into methane or hydrocarbon fuels. Thus, it is entirely possible that sewage of a metropolitan area could be utilized as fuel for generating electricity . . . as water suitable for industrial use . . . as feed for livestock.

Accelerated Conversion Rate

The space vehicle version of this process is represented schematically at the right. Single-celled green algae carry out the reaction of green plants, while man — aided by bacteria — carries out the role of the animal kingdom.

Solid and liquid wastes are converted by bacteria through oxidation into products which serve as nutrient for the algae. Water is rendered suitable for re-use. Carbon dioxide given off by man and bacteria is synthesized by algae into cellular material through the application of solar energy. In so doing, oxygen is released and used by the crew and bacteria.

The process is cyclic, except that algae are stored instead of being re-cycled as food. It is interesting to note that the conversion rate is potentially 20-30 times faster than in the conventional agriculture-food-sewage-agriculture cycle.

The Weight Problem

In its present state of development, the space travel package has a total weight requirement of from 300 to 400 lbs. per man for voyages of virtually any length of time. This estimate includes overall weight of

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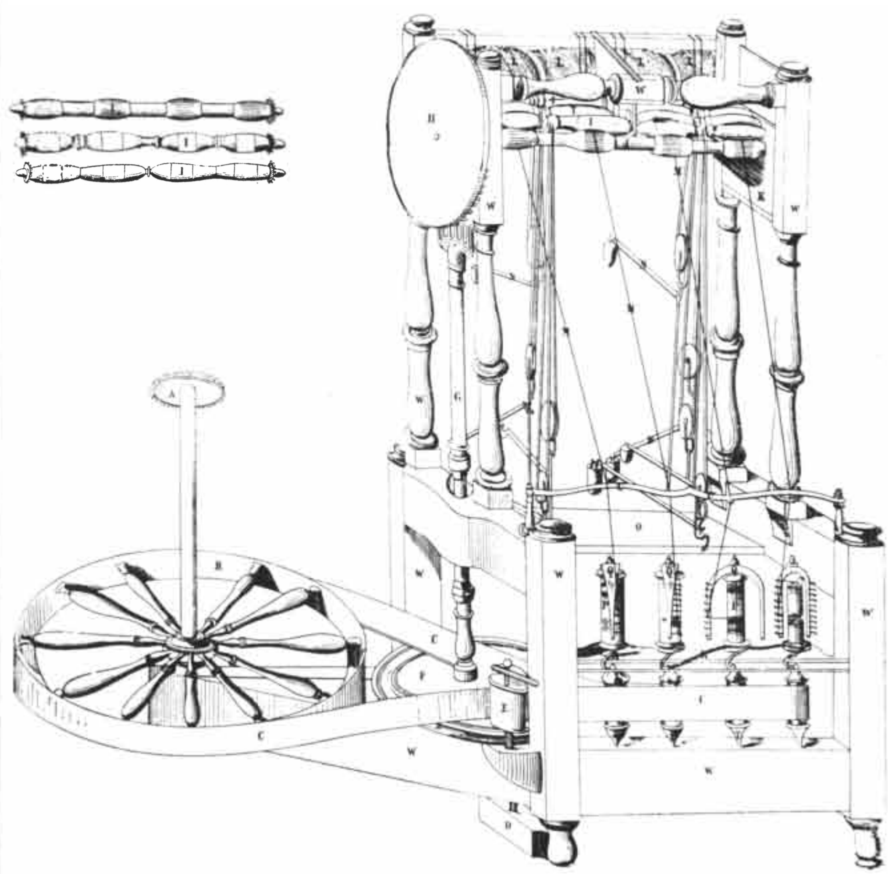
verse. By the end of the period this branch of science had come almost to the edge of the Darwinian theory of evolution. For the rest, if there was further scientific "revolution" in the 18th century, it was in the field of chemistry. At the beginning of the period it had not been possible to isolate a gas or even to recognize clearly that different gases existed. In the last quarter of the century Lavoisier reshaped this whole branch of science; water, which had been regarded for thousands of years as an element, was now seen to be a compound of oxygen and hydrogen.

By this time England—the nation of shopkeepers—was surprising the world with developments in the industrial field. A class of men had emerged who were agile in intellect, capable of self-help and eager for novel enterprises. They often lacked the classical education of the time, and were in a sense cut off from their cultural inheritance; and they no longer had the passion to intervene in theological controversy. Science and craftsmanship, combined with the state of the market, enabled them, however, to indulge their zeal for gadgets, mechanical improvements and inventions.

A considerable minor literature of the time gives evidence of the widespread passion for the production of technical devices, a passion encouraged sometimes by the policy of the government. Between 1760 and 1785 more patents were taken out than in the preceding 60 years; and of the estimated total of 26,000 patents for the whole century, about half were crowded into the 15 years after 1785. In 1761 the Society for the Encouragement of the Arts, Manufactures and Commerce, established a few years earlier, offered a prize for an invention that would enable six threads to be spun by a single pair of hands. A few years later Hargreave's spinning jenny and Arkwright's water frame appeared. The first steam engine had emerged at the beginning of the century, but textile factories began by using water power. The change to steam both here and in the production of iron greatly intensified the industrial revolution that was to alter the landscape so profoundly in the 19th century.

The country was able to meet the needs of a rapidly expanding population, especially as industrial development was accompanied by an agrarian revolution—the birth of something like modern



SPINNING FRAME, patented by Richard Arkwright in 1769, produced superior yarn. In his application the inventor said the machine would be of "great utility" to manufacturers and to the public "by employing a great number of poor people in working said machinery."

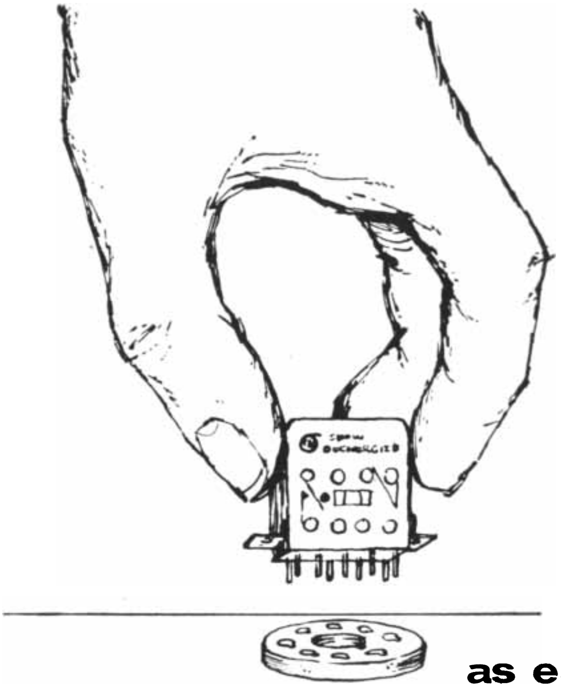
farming. Possibly as a result of a change in the prevalent type of rat, England ceased to suffer from the plague that had ravaged it for centuries. Advances in public-health techniques helped reduce the death rate, especially among infants. During the 18th century the English population rose from 5.5 to nine million. And people flocked to swell the growing industrial towns, as though assured that they were fleeing from something worse to something better.

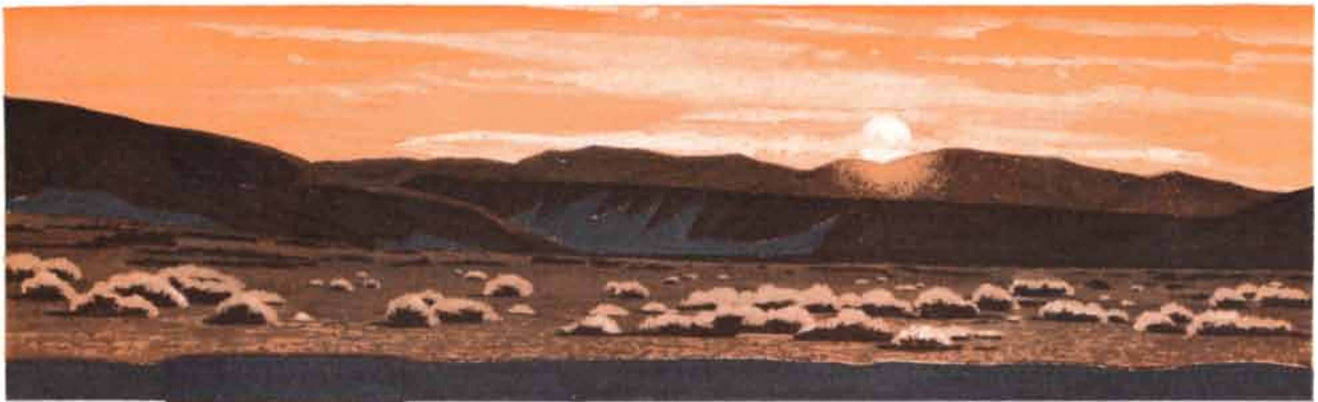
Even in 1700 most Englishmen were still engaged in occupations of a primary nature, connected with farming, fishing, mining and so on. London had perhaps half a million inhabitants, but Bristol, which came next, may have had only 20,000. Very few towns had a population exceeding 10,000. Each country town had its miller, its brewer, its tanner and so on; each village had its baker, its blacksmith and its cobbler. Many of the people who were employed in industry —in the making of textiles, for example —carried on the work in their own homes with hand looms and spinning wheels; they supplemented their income by farming.

The coming of the factory system and the growth of towns represented an unprecedented transformation of life and of the human environment, besides speeding up the rate of all future change. This denser and more complicated world required more careful policing, more elaborate administration and a tremendous increase in the tasks of government. The mere growth and distribution of population, and the fresh disposition of forces that it produced within society, are fundamental factors in the history of the 19th century.

With gathering momentum came railways, the use of electricity, the internal-combustion engine and today the world of electronics and nuclear weapons. Science, so long an aid to the inventor, now seems itself to need the engineer and the industrial magnate. And all the elaborate apparatus of this technical civilization is easily communicable to every quarter of the globe. Our scientific-industrial revolution is a historical landmark for those peoples to whom Renaissance and Reformation have no relevance, since Christianity and Greek antiquity are not in their tradition. The material apparatus of our civilization is more communicable to other continents than are our more subtle and imponderable ideas.

Yet the humanism that has its roots so far back in our history has by no means lost its hold on the world. In the





West, indeed, it now touches vastly wider classes of peoples than were able to read at all before the days of the industrial revolution. That revolution requires the spread of education, and at the same time provides the apparatus for it. The extraordinary speeding-up of communications and the increased mobility of life have themselves had colossal educative results. It was under the ancient order that the peasantry were sometimes felt to be like cows; John Wesley, although he held so firmly that the lowest classes were redeemable, himself described them with astonishing frequency as wild beasts. The new era has raised the stature of men, not lowered it, as some have imagined; and seems to require (or to produce) a more genuine kind of moral autonomy.

Great literature is perhaps more widely appreciated at the present day than ever in previous history. The rights and freedoms of man and the independence and self-respect of nations have never been more glorified than in our own century. And we have transmitted these ideals to other parts of the globe. The scientific-industrial revolution has operated to a great saving of life. At the same time it has provided a system which, where it has prevailed, has so far enabled the expanded population to live.

The vastness of populations and the character of the technical revolution itself have led, however, to certain dangers. The development of high-powered organization means that a colossal machine can now be put at the service of a possible dictatorship. It is not yet clear that the character of the resulting civilization will necessarily undermine the dictatorship and produce the re-establishment of what we call Western values. In this sense the elaborate nature of the system may come to undermine that wonderful individualism that gave it its start. At the same time, when nations are ranged against one another, each may feel forced to go on elaborating and enlarging ever more terrible weapons, though no nation wants them or ever intends to use them. Weapons may then defeat their own ends, and man may find himself the slave of the machine.

The Western ideal of democracy is older than the scientific-industrial revolution, but it may eventually prove a necessary concomitant of that revolution, wherever the revolution may spread. At this point we simply do not know. There are certain things we cannot achieve without tools. But the tools in themselves do not necessarily determine our destiny.

ROMAN TOMBSTONE from the first century A.D. records the death of Cominia Tyche, aged 27 years, 11 months, 28 days. Tombstones are a source of information on life expectancy in the ancient world. Stone is in the Metropolitan Museum of Art in New York.

The Human Population

In the short span of his existence man has come to consume more food than all other land animals put together. This raises the question of how many men the earth can support

by Edward S. Deevey, Jr.

Almost until the present turn in human affairs an expanding population has been equated with progress. "Increase and multiply" is the Scriptural injunction. The number of surviving offspring is the measure of fitness in natural selection. If number is the criterion, the human species is making great progress. The population, now passing 2.7 billion, is doubling itself every 50 years or so. To some horrified observers, however, the population increase has become a "population explosion." The present rate of increase, they point out, is itself increasing. At 1 per cent per year it is double that of the past few centuries. By A.D. 2000, even according to the "medium" estimate of the careful demographers of the United Nations, the rate of increase will have accelerated to 3 per cent per year, and the total population will have reached 6.267 billion. If Thomas Malthus's assumption of a uniform rate of doubling is naive, because it so quickly leads to impossible numbers, how long can an accelerating annual increase, say from 1 to 3 per cent in 40 years, be maintained? The demographers confronted with this question lower their eyes: "It would be absurd," they say, "to carry detailed calculations forward into a more remote future. It is most debatable whether the trends in mortality and fertility can continue much longer. Other factors may eventually bring population growth to a halt."

So they may, and must. It comes to this: Explosions are not made by force alone, but by force that exceeds restraint. Before accepting the implications of the population explosion, it is well to set the present in the context of the record of earlier human populations. As will be seen, the population curve has moved upward stepwise in response to the three major revolutions that have marked the evolution of culture [*see bottom illustration on page 198*]. The tool-using and toolmaking revolution that started the growth of the human stem from the primate line gave the food-gatherer and hunter access to the widest range of environments. Nowhere was the population large, but over the earth as a whole it reached the not insignificant total of five million, an average of .04 person per square kilometer (.1 person per square mile) of land. With the agricultural revolution the population moved up two orders of magnitude to a new plateau, multiplying 100 times in the short span of 8,000 years, to an average of one person per square kilometer. The increase over the last 300 years, a multiplication by five, plainly reflects the first repercussions of the scientific-industrial revolution. There are now 16.4 persons per square kilometer of the earth's land area. It is thus the release of restraint that the curve portrays at three epochal points in cultural history.

But the evolution of the population size also indicates the approach to equilibrium in the two interrevolutionary periods of the past. At what level will the present surge of numbers reach equilibrium? That is again a question of restraint, whether it is to be imposed by the limitations of man's new command over his environment or by his command over his own nature.

The human generative force is neither new nor metabiological, nor is it especially strong in man as compared to other animals. Under conditions of maximal increase in a suitable environment empty of competitors, with births at maximum and deaths negligible, rats can multiply their numbers 25 times in an average generation-time of 31 weeks. For the water flea *Daphnia*, beloved by ecologists for the speedy answers it gives, the figures are 221 times in a generation of 6.8 days. Mankind's best efforts seem puny by contrast: multiplication by about 1.4 times in a generation of 28 years. Yet neither in human nor in experimental populations do such rates continue unchecked. Sooner or later the births slow down and the deaths increase, until—in experiments, at any rate—the growth tapers off, and the population effectively saturates its space. Ecologists define this state (of zero rate of change) as equilibrium, without denying the possibility of oscillations that average out to zero, and without forgetting the continuous input of energy (food, for instance) that is needed to maintain the system.

Two kinds of check, then, operate to limit the size of a population, or of any living thing that grows. Obviously the environment (amount of space, food or other needed resources) sets the upper limit; sometimes this is manipulatable, even by the population itself, as when it exploits a new kind of food in the same old space, and reaches a new, higher limit. More subtly, populations can be said to limit their own rates of increase. As the numbers rise, female fruit-flies, for example, lay fewer eggs when jostled by their sisters; some microorganisms battle each other with antibiotics; flour beetles accidentally eat their own defenseless eggs and pupae; infectious diseases spread faster, or become more virulent, as their hosts become more numerous. For human populations pestilence and warfare, Malthus's "natural restraints," belong among these devices for self-limitation. So, too, does his "moral restraint," or voluntary birth control. Nowadays a good deal of attention is being given, not only to voluntary methods,

YEARS AGO	CULTURAL STAGE	AREA POPULATED	ASSUMED DENSITY PER SQUARE KILOMETER	TOTAL POPULATION (MILLIONS)
1,000,000	LOWER PALEOLITHIC		.00425	.125
300,000	MIDDLE PALEOLITHIC		.012	1
25,000	UPPER PALEOLITHIC		.04	3.34
10,000	MESOLITHIC		.04	5.32
6,000	VILLAGE FARMING AND EARLY URBAN		 1.0 .04	86.5
2,000	VILLAGE FARMING AND URBAN		 1.0	133
310	FARMING AND INDUSTRIAL		 3.7	545
210	FARMING AND INDUSTRIAL		 4.9	728
160	FARMING AND INDUSTRIAL		 6.2	906
60	FARMING AND INDUSTRIAL		 11.0	1,610
10	FARMING AND INDUSTRIAL		 16.4	2,400
A. D. 2000	FARMING AND INDUSTRIAL		 46.0	6,270

but also to a fascinating new possibility: mental stress.

Population control by means of personality derangement is probably a vertebrate patent; at least it seems a luxury beyond the reach of a water flea. The general idea, as current among students of small mammals, is that of hormonal imbalance (or stress, as defined by Hans Selye of the University of Montreal); psychic tension, resulting from overcrowding, disturbs the pituitary-adrenal system and diverts or suppresses the hormones governing sexuality and parental care. Most of the evidence comes from somewhat artificial experiments with caged rodents. It is possible, though the case is far from proved, that the lemming's famous mechanism for restoring equilibrium is the product of stress; in experimental populations of rats and mice, at least, anxiety has been observed to increase the death rate through fighting or merely from shock.

From this viewpoint there emerges an interesting distinction between crowding and overcrowding among vertebrates; overcrowding is what is perceived as such by members of the population. Since the human rate of increase is holding its own and even accelerating, however, it is plain that the mass of men, although increasingly afflicted with mental discomfort, do not yet see themselves as overcrowded. What will happen in the future brings other questions. For the present it may be noted that some kind of check has always operated, up to now, to prevent populations from exceeding the space that contains them. Of course space may be non-Euclidean, and man may be exempt from this law.

The commonly accepted picture of the growth of the population out of the long past takes the form of the top graph on the next page. Two things are wrong with this picture. In the first place the basis of estimates, back of about A.D. 1650, is rarely stated. One suspects that writers have been copying each other's guesses. The second defect is that the scales of the graph have been chosen so as to make the first defect seem unimportant. The missile has left the pad and is heading out of sight—so it is said; who cares whether there were a million or a hundred million people around when Babylon was founded? The difference is nearly lost in the thickness of the draftsman's line.

I cannot think it unimportant that (as I calculate) there were 36 billion Paleolithic hunters and gatherers, including the first tool-using hominids. One begins to see why stone tools are among the commonest Pleistocene fossils. Another 30 billion may have walked the earth before the invention of agriculture. A cumulative total of about 110 billion individuals seem to have passed their days, and left their bones, if not their marks, on this crowded planet. Neither for our understanding of culture nor in terms of man's impact upon the land is it a negligible consideration that the patch of ground allotted to every person now alive may have been the lifetime habitat of 40 predecessors.

These calculations exaggerate the truth in a different way: by condensing into single sums the enormous length of prehistoric time. To arrive at the total of 36 billion Paleolithic hunters and gatherers I have assumed mean standing populations of half a million for the Lower Paleolithic, and two million for the Middle and Upper Paleolithic to 25,000 years ago. For Paleolithic times there are no archeological records worth considering in such calculations. I have used some figures for modern hunting tribes, quoted by Robert J. Braidwood and Charles A. Reed, though they are not guilty of my extrapolations. The assumed densities per square kilometer range from a tenth to a third of those estimated for eastern North America before Columbus came, when an observer would hardly have described the woods as full of Indians. (Of course I have excluded any New World population from my estimates prior to the Mesolithic climax of the food-gathering and hunting phase of cultural evolution.) It is only because average generations of 25 years succeeded each other 39,000 times that the total looms so large.

For my estimates as of the opening of the agricultural revolution, I have also depended upon Braidwood and Reed. In their work in Mesopotamia they have counted the number of rooms in buried houses, allowing for the areas of town sites and of cultivated land, and have compared the populations so computed with modern counterparts. For early village-farmers, like those at Jarmo, and for the urban citizens of Sumer, about 2500 B.C., their estimates (9.7 and 15.4 persons per square kilometer) are probably fairly close. They are intended to apply to large tracts of inhabited country, not to pavement-bound clusters of artisans and priests. Nevertheless, in extending these estimates to continent-wide areas, I have divided the lower figure by 10, making it one per square kilometer. So much of Asia is unirrigated and nonurban even today that the figure may still be too high. But the Maya, at about the same level of culture (3,000 or 4,000 years later), provide a useful standard of comparison. The present population of their classic homeland averages .6 per square kilometer, but the land can support a population about a hundred times as large, and probably did at the time of the classic climax. The rest of the New World, outside Middle America, was (and is) more thinly settled, but a world-wide average of one per square kilometer seems reasonable for agricultural, pre-industrial society.

For modern populations, from A.D. 1650 on, I have taken the estimates of economic historians, given in such books as the treatise *World Population and Production*, by Wladimir S. and Emma S. Woytinsky. All these estimates are included in the bottom graph on the next page. Logarithmic scales are used in order to compress so many people and millennia onto a single page. Foreshortening time in this way is convenient, if not particularly logical, and back of 50,000 years ago the time-scale is pretty arbitrary anyway. No attempt is made to show the oscillations that probably occurred, in glacial and interglacial ages, for example.

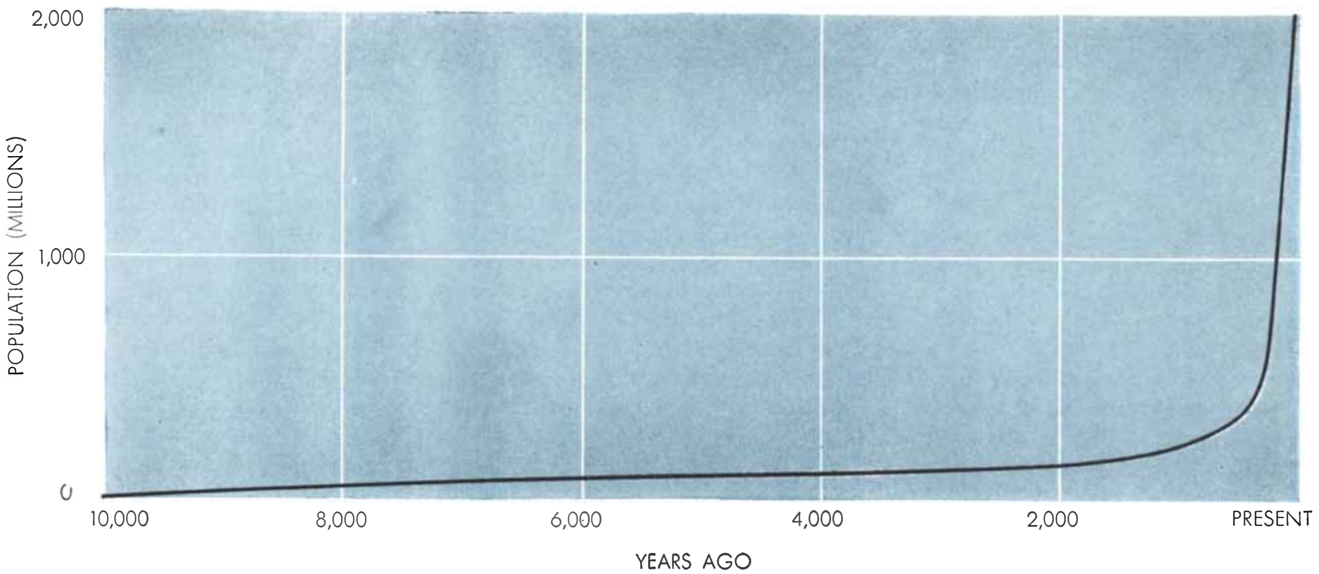
The stepwise evolution of population size, entirely concealed in graphs with arithmetic scales, is the most noticeable feature of this diagram. For most of the million-year period the number of hominids, including man, was about what would be expected of any large Pleistocene mammal—scarcer than

POPULATION GROWTH, from inception of the hominid line one million years ago through the different stages of cultural evolution to A.D. 2000, is shown in the chart on the opposite page. In Lower Paleolithic stage, population was restricted to Africa (*colored area on world map in third column*), with a density of only .00425 person per square kilometer (*fourth column*) and a total population of only 125,000 (*column at right*). By the Mesolithic stage, 10,000 years ago, hunting and food gathering techniques had spread the population over most of the earth and brought the total to 5,320,000. In the village farming and early urban stage, population increased to a total of 86,500,000 and a density of one person per square kilometer in the Old World and .04 per square kilometer in the New World. Today the population density exceeds 16 persons per square kilometer, and pioneering of the antarctic continent has begun.

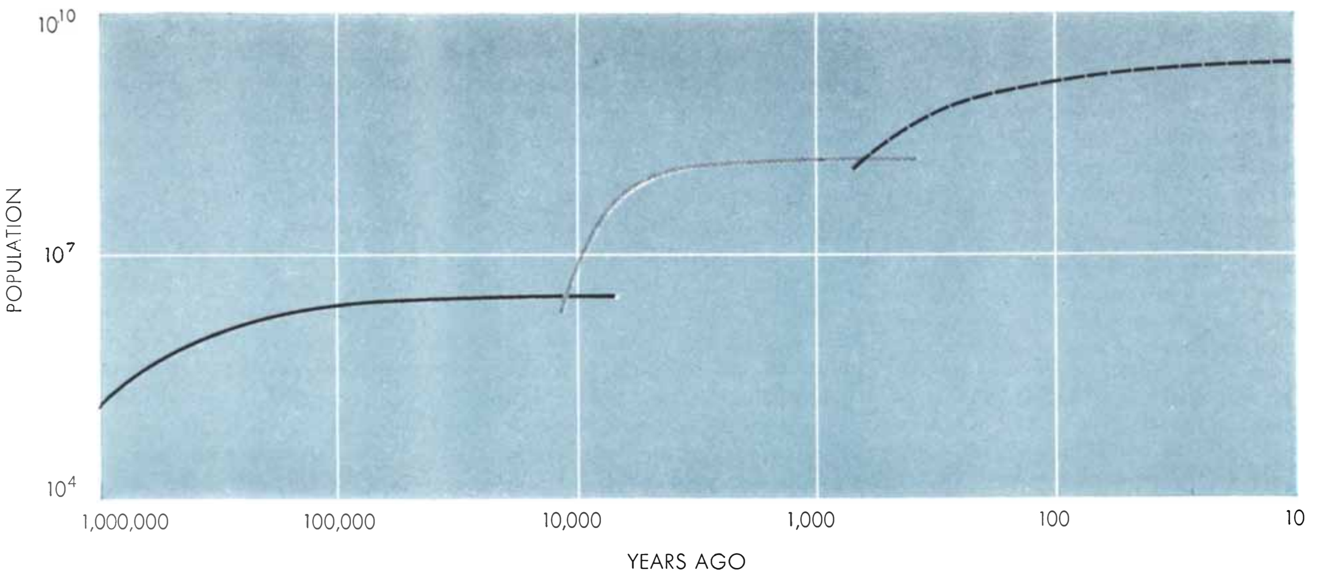
horses, say, but commoner than elephants. Intellectual superiority was simply a successful adaptation, like longer legs; essential to stay in the running, of course, but making man at best the first among equals. Then the food-gatherers and hunters became plowmen and herdsmen, and the population was boosted by about 16 times, between 10,000 and 6,000 years ago. The scientific-industrial revolution, beginning some 300 years ago, has spread its effects much faster, but it has not yet taken the number as far above the earlier base line.

The long-term population equilibrium implied by such base lines suggests something else. Some kind of restraint kept the number fairly stable. "Food supply" offers a quick answer, but not, I think, the correct one. At any rate, a forest is full of game for an expert mouse-hunter, and a Paleolithic man who stuck to business should have found enough food on two square kilometers, instead of 20 or 200. Social forces were probably more powerful than mere starvation in causing men to huddle in small bands. Besides, the number was presumably adjusted to conditions in the poorest years, and not to average environments.

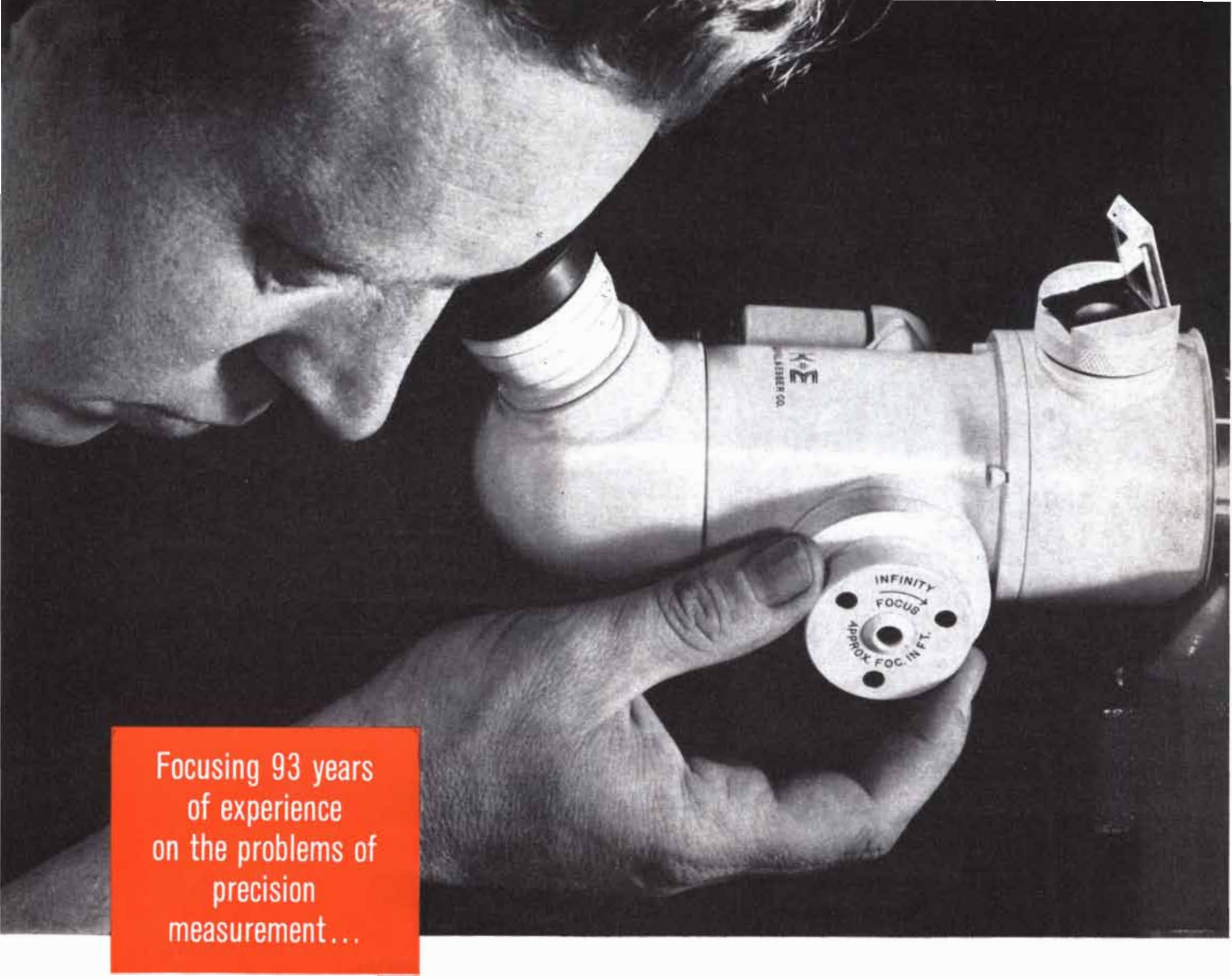
The main point is that there were adjustments. They can only have come about because the average female bore two children who survived to reproduce. If the average life span is 25 years, the "number of children ever born" is about four (because about 50 per cent die before breeding), whereas a population that is really trying can average close to eight. Looking back on former times, then, from our modern point of view, we might say that about two births out of four were surplus, though they were needed to counterbalance the juvenile death toll. But what about the other four, which evidently did not occur? Unless the life expectancy was very much less



ARITHMETIC POPULATION CURVE plots the growth of human population from 10,000 years ago to the present. Such a curve suggests that the population figure remained close to the base line for an indefinite period from the remote past to about 500 years ago, and that it has surged abruptly during the last 500 years as a result of the scientific-industrial revolution.



LOGARITHMIC POPULATION CURVE makes it possible to plot, in a small space, the growth of population over a longer period of time and over a wider range (from 10^4, or 10,000, to 10^{10}, or 10 billion, persons). Curve, based on assumptions concerning relationship of technology and population as shown in chart on page 196, reveals three population surges reflecting toolmaking or cultural revolution (*solid line*), agricultural revolution (*gray line*) and scientific-industrial revolution (*broken line*).



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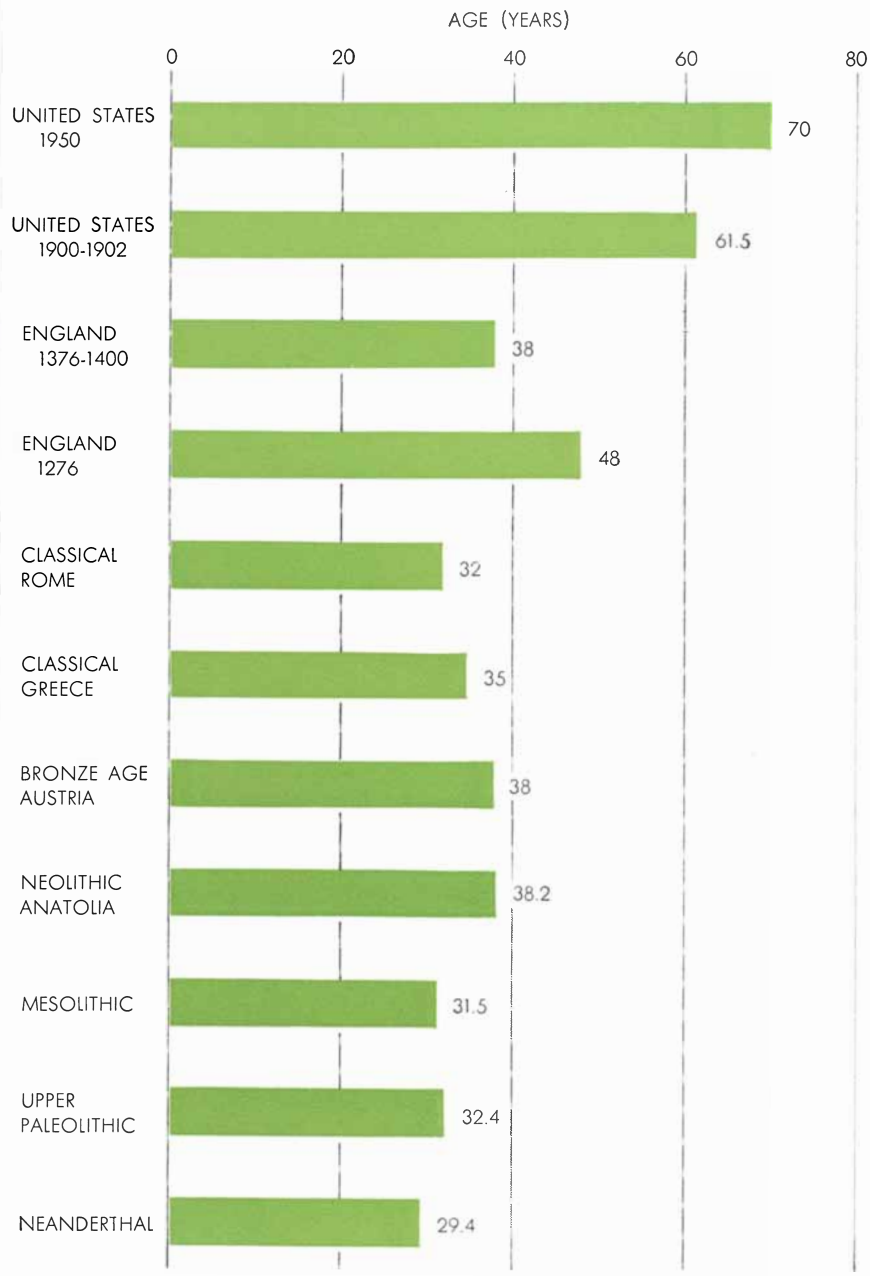
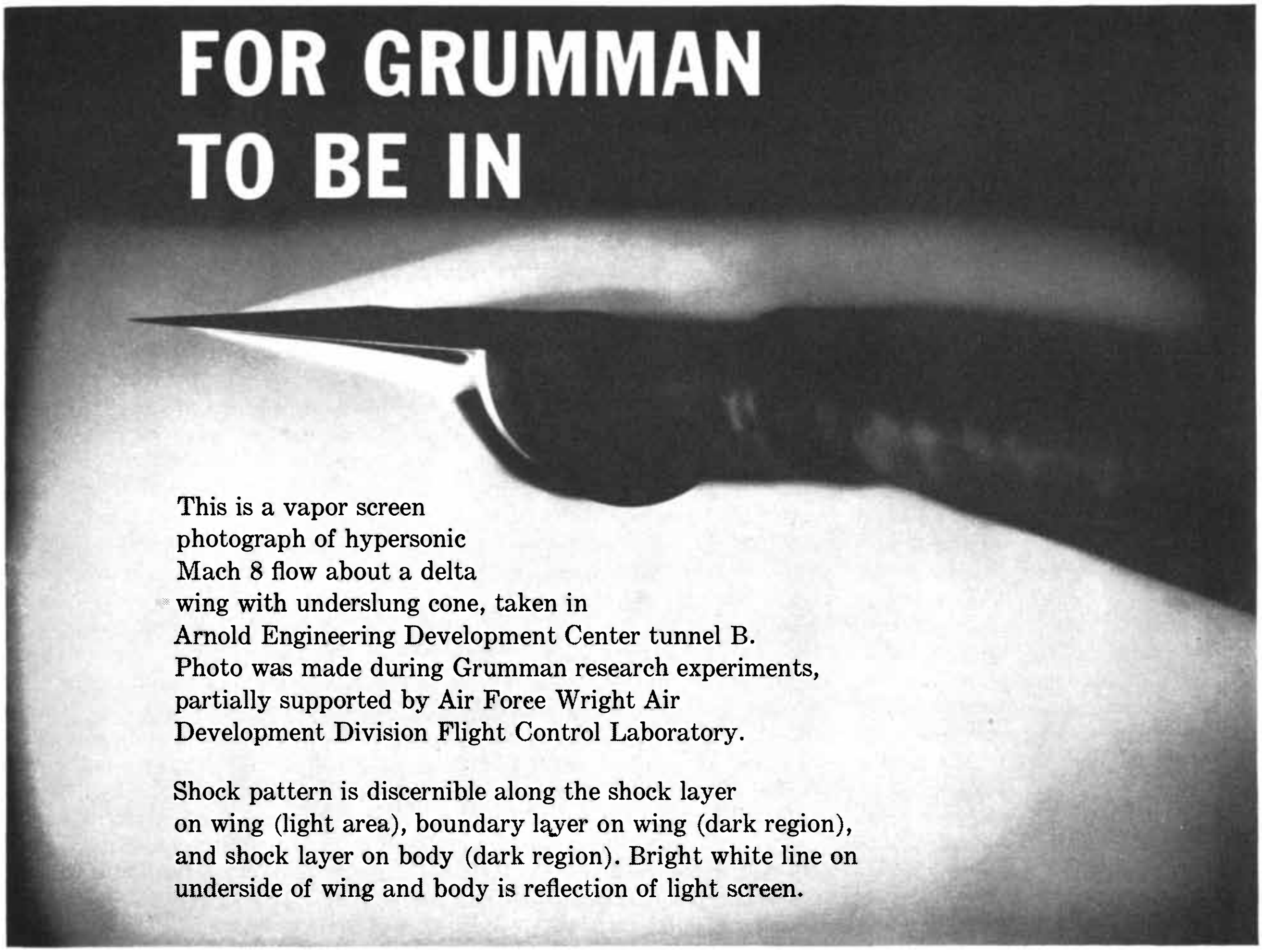
____1515 than I have assumed (and will presently justify), some degree of voluntary birth control has always prevailed.

Our 40 predecessors on earth make an impressive total, but somehow it sounds different to say that nearly 3 per cent of the people who have ever lived are still around. When we realize that they are living twice as long as their parents did, we are less inclined to discount the revolution in which we are living. One of its effects has just begun to be felt: The mean age of the population is increasing all over the world. Among the more forgivable results of Western culture, when introduced into simpler societies, is a steep drop in the death rate. Public-health authorities are fond of citing Ceylon in this connection. In a period of a year during 1946 and 1947 a campaign against malaria reduced the death rate there from 20 to 14 per 1,000. Eventually the birth rate falls too, but not so fast, nor has it yet fallen so far as a bare replacement value. The natural outcome of this imbalance is that acceleration of annual increase which so bemuses demographers. In the long run it must prove to be temporary,



LONGEVITY in ancient and modern times is charted. From time of Neanderthal man to 14th century A.D., life span appears to have hovered around 35 years. An exception is 13th-century England. Increase in longevity partly responsible for current population increase has come in modern era. In U.S. longevity increased about 10 years in last half-century.

NOTHING IS TOO FAR OUT....



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unless the birth rate accelerates, for the deaths that are being systematically prevented are premature ones. That is, the infants who now survive diphtheria and measles are certain to die of something else later on, and while the mean life-span is approaching the maximum, for the first time in history, there is no reason to think that the maximum itself has been stretched. Meanwhile the expectation of life at birth is rising daily in most countries, so that it has already surpassed 70 years in some, including the U. S., and probably averages between 40 and 50.

It is hard to be certain of any such world-wide figure. The countries where mortality is heaviest are those with the least accurate records. In principle, however, mean age at death is easier to find out than the number of children born, the frequency or mean age at marriage, or any other component of a birth rate. The dead bones, the court and parish records and the tombstones that archeology deals with have something to say about death, of populations as well as of people. Their testimony confirms the impression that threescore years and ten, if taken as an average and not as a maximum lifetime, is something decidedly new. Of course the possibilities of bias in such evidence are almost endless. For instance, military cemeteries tend to be full of young adult males. The hardest bias to allow for is the deficiency of infants and children; juvenile bones are less durable than those of adults, and are often treated less respectfully. Probably we shall never know the true expectation of life at birth for any ancient people. Bypassing this difficulty, we can look at the mean age at death among the fraction surviving to adolescence.

The "nasty, brutish and short" lives of Neanderthal people have been rather elaborately guessed at 29.4 years. The record, beyond them, is not one of steady improvement. For example, Neolithic farmers in Anatolia and Bronze Age Austrians averaged 38 years, and even the Mesolithic savages managed more than 30. But in the golden ages of Greece and Rome the life span was 35 years or less. During the Middle Ages the chances of long life were probably no better. The important thing about these averages is not the differences among them, but their similarity. Remembering the crudeness of the estimates, and the fact that juvenile mortality is omitted, it is fair to guess that human life-expectancy at birth has never been far from 25 years—25 plus or minus five, say—from Neanderthal times up to the present century. It follows, as I have said, that about half the children ever born have lived to become sexually mature. It is not hard to see why an average family size of four or more, or twice the minimum replacement rate, has come to seem part of a God-given scheme of things.

The 25-fold upsurge in the number of men between 10,000 and 2,000 years ago was sparked by a genuine increase in the means of subsistence. A shift from animal to plant food, even without agricultural labor and ingenuity, would practically guarantee a 10-fold increase, for a given area can usually produce about 10 times as much plant as animal substance. The scientific-industrial revolution has increased the efficiency of growing these foods, but hardly, as yet, beyond the point needed to support another 10 times as many people, fewer of whom are farmers. At the present rate of multiplication, without acceleration, another 10-fold rise is due within 230 years. Disregarding the fact that developed societies spend 30 to 60 times as much energy for other purposes as they need for food, one is made a little nervous by the thought of so many hungry mouths. Can the increase of efficiency keep pace? Can some of the apparently ample energy be converted to food as needed, perhaps at the cost of reducing the size of Sunday newspapers? Or is man now pressing so hard on his food supply that another 10-fold increase of numbers is impossible?

The answers to these questions are not easy to find, and students with different viewpoints disagree about them. Richard L. Meier of the University of Michigan estimates that a total of 50 billion people (a 20-fold increase, that is) can be supported on earth, and the geochemist Harrison Brown of the California Institute of Technology will allow (reluctantly) twice or four times as many. Some economists are even more optimistic; Arnold C. Harberger of the University of Chicago presents the interesting notion that a larger crop of people will contain more geniuses, whose intellects will find a solution to the problem of feeding *still* more people. And the British economist Colin Clark points out that competition for resources will sharpen everyone's wits, as it always has, even if the level of innate intelligence is not raised.

An ecologist's answer is bound to be cast in terms of solar energy, chlorophyll and the amount of land on which the two can interact to produce organic carbon. Sources of energy other than the sun are either too expensive, or nonrenewable or both. Land areas will continue for a very long time to be the places where food is grown, for the sea is not so productive as the land, on the average. One reason, sometimes forgotten, is that the plants of the sea are microscopic algae, which, being smaller than land plants, respire away a larger fraction of the carbon they fix. The culture of the fresh-water alga *Chlorella* has undeniable promise as a source of human food. But the high efficiencies quoted for its photosynthesis, as compared with agricultural plants, are not sustained outdoors under field conditions. Even if Chlorella (or another exceptionally efficient producer, such as the water hyacinth) is the food plant of the future, flat areas exposed to sunlight will be needed. The 148.5 million square kilometers of land will have to be used with thoughtful care if the human population is to increase 20-fold. With a population of 400 per square kilometer (50 billion total) it would seem that men's bodies, if not their artifacts, will stand in the way of vital sunshine.

Plants capture the solar energy impinging on a given area with an efficiency of about .1 per cent. (Higher values often quoted are based on some fraction of the total radiation, such as visible light.) Herbivores capture about a 10th of the plants' energy, and carnivores convert about 10 per cent of the energy captured by herbivores (or other carnivores). This means, of course, that carnivores, feeding on plants at second hand, can scarcely do so with better than 1 per cent efficiency (1/10 × 1/10 equals 1/100). Eugene I. Rabinowitch of the University of Illinois has calculated that the current crop of men represents an ultimate conversion of about 1 per cent of the energy trapped by land vegetation. Recently, however, I have re-examined the base figure—the efficiency of the land-plant production—and believe it should be raised by a factor of three or four. The old value came from estimates made in 1919 and in 1937. A good deal has been learned since those days. The biggest surprise is the high productivity of forests, especially the forests of the Temperate Zone.

If my new figures are correct, the population could theoretically increase by 30 or 40 times. But man would have to displace all other herbivores and utilize all the vegetation with the 10 per cent efficiency established by the ecological rule of tithes. No land that now supports greenery could be spared for nonagricultural purposes; the populace would have to reside in the polar regions, or on artificial "green isles in the

	CHARACTER OF VEGETATION	AREA (MILLIONS OF SQUARE KILOMETERS)	NET PRODUCTION PER YEAR (GRAMS OF CARBON PER SQUARE METER)	NET PRODUCTION PER YEAR (MILLIONS OF TONS OF CARBON)
CULTIVATED	GRAIN	6.74	149	1,000
	POTATOES	.23	154	34.6
	SUGAR BEETS	.04	306	12.2
	OTHER	6.3	200	1,260
FOREST	CONIFEROUS	14.6	1,272	18,600
	DECIDUOUS	5.66	625	3,540
	TROPICAL	20.25	1,200	24,400
	TAIGA	3.9	400	1,560
GRASSLANDS	HUMID	14.9	179	2,670
	SEMI-ARID	22.0	28	616
OTHER	WETLANDS	3.3	690	2,280
	DESERT	22.4	16	358
	TUNDRA	8.5	8	68
	PERPETUAL FROST	19.7	0	0
TOTAL NET	LAND	148.5	380 (MEAN)	56,400
	SEA	371.0	90 (MEAN)	33,400
	WORLD			89,800
TOTAL GROSS	LAND			73,000
	SEA			67,000
	WORLD			140,000

PRODUCTION OF ORGANIC MATTER per year by the land vegetation of the world—and thus its ultimate food-producing capacity—is charted in terms of the amount of carbon incorporated in organic compounds. Cultivated vegetation (*top left*) is less efficient than forest and wetlands vegetation, as indicated by the uptake of carbon per square meter (*third column*), and it yields a smaller over-all output than forest, humid grasslands and wetlands vegetation (*fourth column*). The scales at top of third and fourth columns are logarithmic. Land vegetation leads sea vegetation in efficiency and in net and gross tonnage (*bottom*). The difference between the net production and gross production is accounted for by the consumption of carbon in plant respiration.

sea, love"—scummed over, of course, by 10 inches of Chlorella culture.

The picture is doubtless overdrawn. There is plenty of room for improvement in present farming practice. More land could be brought under cultivation if a better distribution of water could be arranged. More efficient basic crops can be grown and used less wastefully. Other sources of energy, notably atomic energy, can be fed back into food production to supplement the sun's rays. None of these measures is more than palliative, however; none promises so much as a 10-fold increase in efficiency; worse, none is likely to be achieved at a pace equivalent to the present rate of doubling of the world's population. A 10-fold, even a 20-fold, increase can be tolerated, perhaps, but the standard of living seems certain to be lower than today's. What happens then, when men perceive themselves to be overcrowded?

The idea of population equilibrium will take some getting used to. A population that is kept stable by emigration, like that of the Western Islands of Scotland, is widely regarded as sick—a shining example of a self-fulfilling diagnosis. Since the fall of the death rate is temporary, it is those two or more extra births per female that demand attention. The experiments with crowded rodents point to one way they might be corrected, through the effect of anxiety in suppressing ovulation and spermatogenesis and inducing fetal resorption. Some of the most dramatic results are delayed until after birth: litters are carelessly nursed, deserted or even eaten. Since fetuses, too, have endocrine glands, the specter of maternal transmission of anxiety now looms: W. R. Thompson of Wesleyan University has shown that the offspring of frustrated mother mice are more "emotional" throughout their own lives, and my student Kim Keeley has confirmed this.

Considered abstractly, these devices for self-regulation compel admiration for their elegance. But there is a neater device that men can use: rational, voluntary control over numbers. In mentioning the dire effects of psychic stress I am not implying that the population explosion will be contained by cannibalism or fetal resorption, or any power so naked. I simply suggest that vertebrates have that power, whether they want it or not, as part of the benefit—and the price—of being vertebrates. And if the human method of adjusting numbers to resources fails to work in the next 1,000 years as it has in the last million, subhuman methods are ready to take over.

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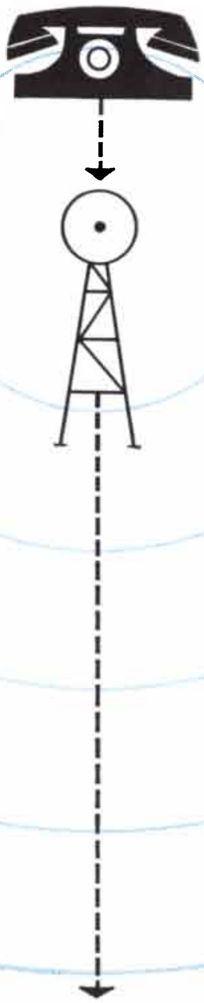

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The Present Evolution of Man

Man still evolves by natural selection for his environment, but it is now an environment largely of his own making. Moreover, he may be changing the environment faster than he can change biologically

by Theodosius Dobzhansky

In tracing the evolution of man, this issue of SCIENTIFIC AMERICAN deals with a natural process that has transcended itself. Only once before, when life originated out of inorganic matter, has there occurred a comparable event.

After that first momentous step, living forms evolved by adapting to their environments. Adaptation—the maintenance or advancement of conformity between an organism and its surroundings—takes place through natural selection. The raw materials with which natural selection works are supplied by mutation and sexual recombination of hereditary units: the genes.

Mutation, sexual recombination and natural selection led to the emergence of *Homo sapiens*. The creatures that preceded him had already developed the rudiments of tool-using, toolmaking and cultural transmission. But the next evolutionary step was so great as to constitute a difference in kind from those before it. There now appeared an organism whose mastery of technology and of symbolic communication enabled it to create a supraorganic culture. Other organisms adapt to their environments by changing their genes in accordance with the demands of the surroundings. Man and man alone can also adapt by changing his environments to fit his genes. His genes enable him to invent new tools, to alter his opinions, his aims and his conduct, to acquire new knowledge and new wisdom.

The authors of the preceding articles have shown how the possession of these faculties brought the human species to its present biological eminence. Man has spread to every section of the earth, bringing high culture to much of it. He is now the most numerous of the mammals. By these or any other reasonable standards, he is by far the most successful product of biological evolution.

For better or worse, biological evolution did not stop when culture appeared. In this final article we address ourselves to the question of where evolution is now taking man. The literature of this subject has not lacked for prophets who wish to divine man's eventual fate. In our age of anxiety, prediction of final extinction has become the fashionable view, replacing the hopes for emergence of a race of demigods that more optimistic authorities used to foresee. Our purpose is less ambitious. What biological evolutionary processes are now at work is a problem both serious and complex enough to occupy us here.

The impact of human works on the environment is so strong that it has become very hard to make out the forces to which the human species is now adjusting. It has even been argued that *Homo sapiens* has already emancipated himself from the operation of natural selection. At the other extreme are those who still assume that man is nothing but an animal. The second fallacy is the more pernicious, leading as it does to theories of biological racism and the justification of race and class prejudice which are bringing suffering to millions of people from South Africa to Arkansas. Assuming that man's genetic endowment can be ignored is the converse falsehood, perhaps less disastrous in its immediate effects, but more insidious in the long run.

Like all other animals, man remains the product of his biological inheritance. The first, and basic, feature of his present evolution is that his genes continue to mutate, as they have since he first appeared. Every one of the tens of thousands of genes inherited by an individual has a tiny probability of changing in some way during his generation. Among the small, and probably atypical, sample of human genes for which very rough estimates of the mutation frequencies are available, the rates of mutation vary from one in 10,000 to one in about 250,000. For example, it has been calculated that approximately one sex cell in every 50,000 produced by a normal person carries a new mutant gene causing retinoblastoma, a cancer of the eye affecting children.

These figures are "spontaneous" frequencies in people not exposed to any special agents that can induce mutation. As is now widely known, the existence of such agents, including ionizing radiation and certain chemicals, has been demonstrated with organisms other than man. New mutagens are constantly being discovered. It can hardly be doubted that at least some of them affect human genes. As a consequence the members of an industrial civilization have increased genetic variability through rising mutation rates.

There is no question that many mutations produce hereditary diseases, malformations and constitutional weaknesses of various kinds. Some few must also be useful, at least in certain environments; otherwise there would be no evolution. (Useful mutants have actually been observed in experiments on lower organisms.) But what about minor variations that produce a little more or a little less hair, a slightly longer or a slightly shorter nose, blood of type O or type A? These traits seem neither useful nor harmful. Here, however, we must proceed with the greatest caution. Beneficial or damaging effects of ostensibly neutral traits may eventually be discovered. For example, recent evidence indicates that people with blood of type O have a slightly higher rate of duodenal ulcer than does the general population. Does it follow that O blood is bad? Not necessarily; it is the most frequent type in many populations, and it may conceivably confer some advantages yet undiscovered.

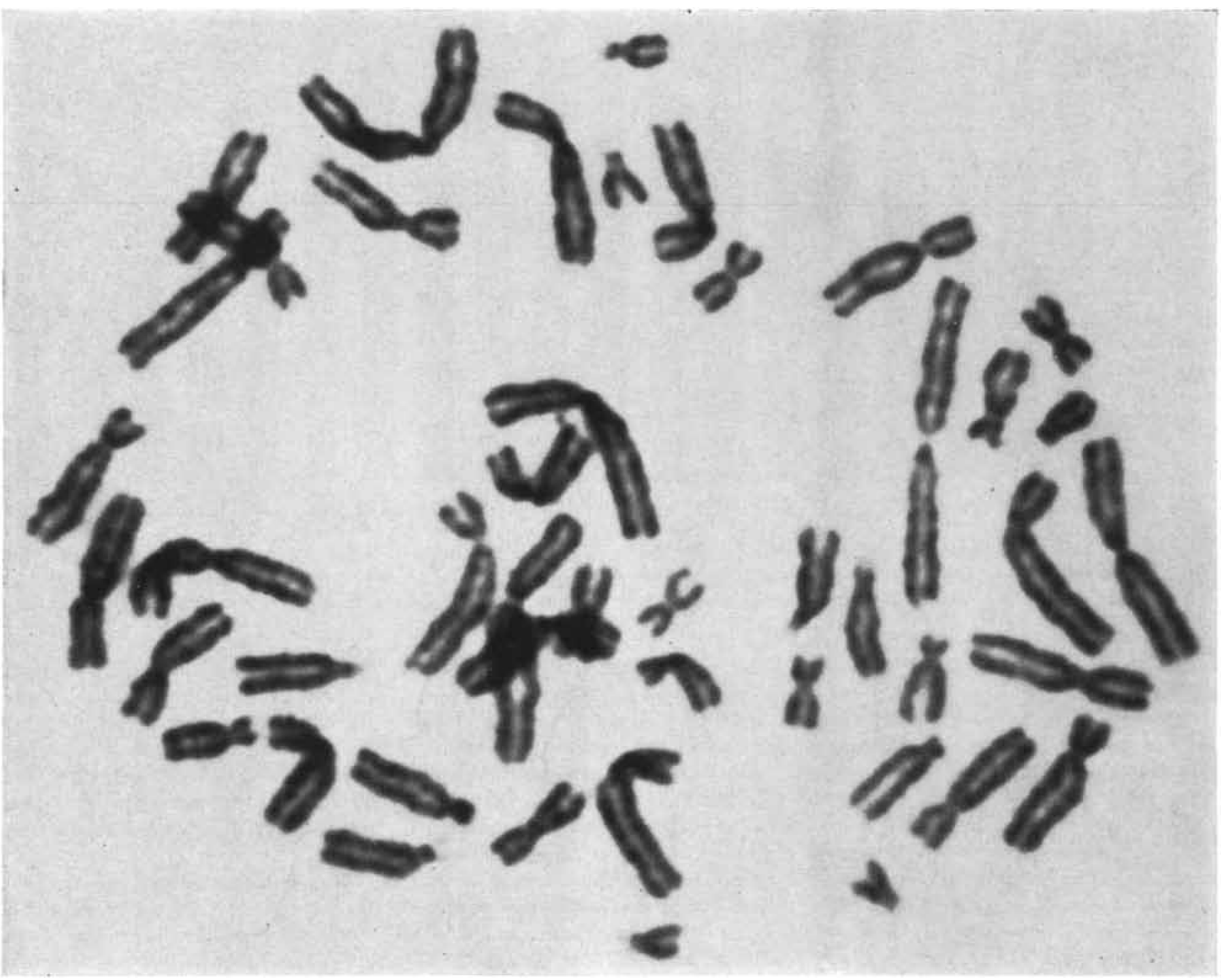
Still other mutants that are detrimental when present in double dose (the so-called homozygous condition, where the same type of gene has been inherited from both parents) lead to hybrid vigor in single dose (the heterozygous condition). How frequently this happens is uncertain. The effect surely operates in the breeding of domestic animals and plants, and it has been detected among X-ray-induced mutations in fruit flies. Only one case is thus far known in man. Anthony C. Allison of the University of Oxford has found that the gene causing sickle-cell anemia in the homozygous condition makes its heterozygous carriers relatively resistant to certain forms of malaria. This gene is very frequent in the native population of the central African lowlands, where malaria has long been endemic, and relatively rare in the inhabitants of the more salubrious highlands. Certainly there are other such adaptively ambivalent genes in human populations, but we do not know how many.

Despite these uncertainties, which cannot be glossed over, it is generally agreed among geneticists that the effects of mutation are on the average detrimental. Any increase of mutation rate, no matter how small, can only augment the mass of human misery due to defective heredity. The matter has rightly attracted wide attention in connection with ionizing radiation from military and industrial operations and medical X-rays. Yet these form only a part of a larger and more portentous issue.

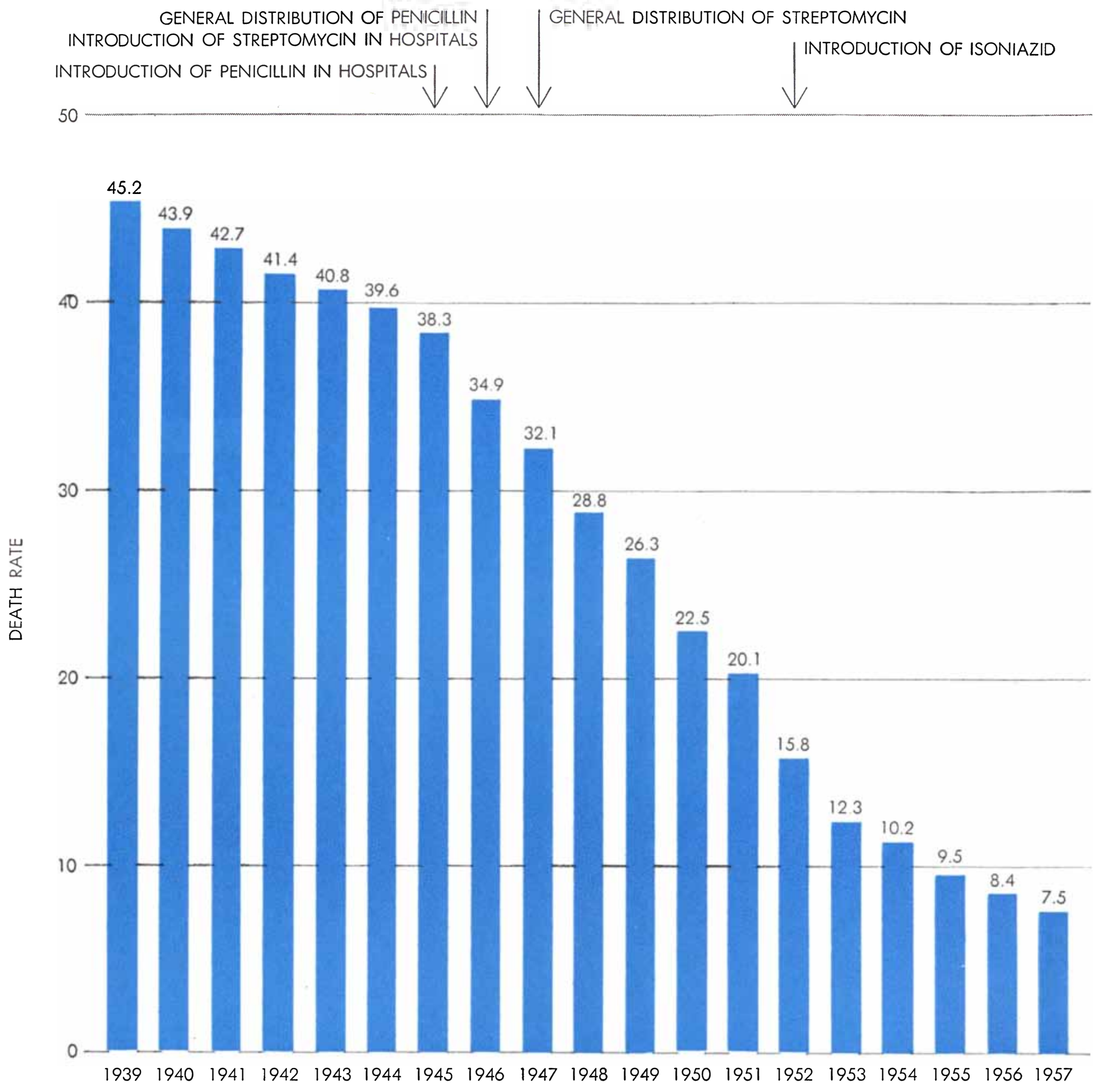
Of the almost countless mutant genes that have arisen since life on earth began, only a minute fraction were preserved. They were preserved because they were useful, or at least not very harmful, to their possessors. A great majority of gene changes were eliminated. The agency that preserved useful mutants and eliminated injurious ones was natural selection. Is natural selection still operating in mankind, and can it be trusted to keep man fit to live in environments created by his civilization?

One must beware of words taken from everyday language to construct scientific terminology. "Natural" in "natural selection" does not mean the state of affairs preceding or excluding man-made changes. Artificially or not, man's environment has altered. Would it now be natural to try to make your living as a Stone Age hunter?

Then there are phrases like "the struggle for life" and "survival of the fittest." Now "struggle" was to Darwin a metaphor. Animals struggle against cold by growing warm fur, and plants against dryness by reducing the evaporating leaf surface. It was the school of so-called social Darwinists (to which Darwin did not belong) who equated "struggle" with violence, warfare and competition



HUMAN CHROMOSOMES are enlarged some 5,000 times in this photomicrograph made by J. H. Tjio and Theodore T. Puck at the University of Colorado Medical Center. The photomicrograph shows all of the 46 pairs of chromosomes in a dividing body cell.



TUBERCULOSIS DEATH RATE per 100,000 people showed a dramatic decline with the introduction of antibiotics and later of the antituberculosis drug isoniazid. As tuberculosis becomes less prevalent, so does its threat to genetically susceptible individuals, who are enabled to survive and reproduce. The chart is based upon information from the U. S. National Office of Vital Statistics.

without quarter. The idea has long been discredited.

We do not deny the reality of competition and combat in nature, but suggest that they do not tell the whole story. Struggle for existence may be won not only by strife but also by mutual help. The surviving fit in human societies may in some circumstances be those with the strongest fists and the greatest readiness to use them. In others they may be those who live in peace with their neighbors and assist them in hour of need. Indeed, co-operation has a long and honorable record. The first human societies, the hunters of the Old Stone Age, depended on co-operation to kill big game.

Moreover, modern genetics shows that "fitness" has a quite special meaning in connection with evolution. Biologists now speak of Darwinian fitness, or adaptive value, or selective value in a reproductive sense. Consider the condition known as achondroplastic dwarfism, caused by a gene mutation that produces people with normal heads and trunks, but short arms and legs. As adults they may enjoy good health. Nevertheless, E. T. Mørch in Denmark has discovered that achondroplastic dwarfs produce, on the average, only some 20 surviving children for every 100 children produced by their normal brothers and sisters. In technical terms we say that the Darwinian fitness of achondroplasts is .2 or, alternatively that achondroplastic dwarfism is opposed by a selection-coefficient of .8.

This is a very strong selection, and the reasons for it are only partly understood. What matters from an evolutionary point of view is that achondroplasts are much less efficient in transmitting their genes to the following generations than are nondwarfs. Darwinian fitness is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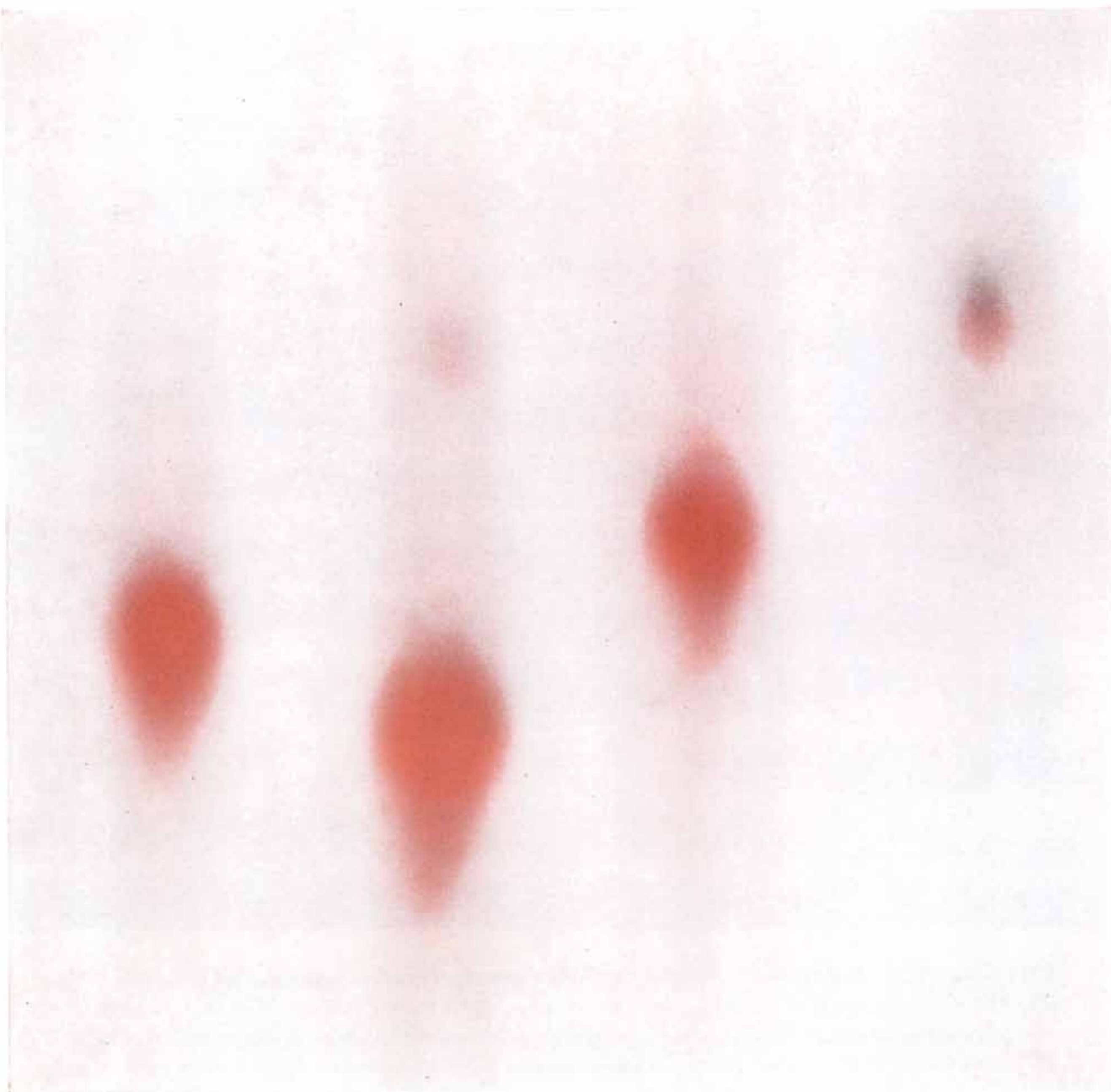
reproductive fitness. Genetically the surviving fittest is neither superman nor conquering hero; he is merely the parent of the largest surviving progeny.

With these definitions in mind, we can answer the question whether natural selection is still active in mankind by considering how such selection might be set aside. If all adults married, and each couple produced exactly the same number of children, all of whom survived to get married in turn and so on, there would be no selection at all. Alternatively, the number of children, if any, that each person produced might be determined by himself or some outside authority on the basis of the desirability of his hereditary endowment. This would be replacing natural selection by artificial selection. Some day it may come to pass. Meantime natural selection is going on.

It goes on, however, always within the context of environment. As that changes, the Darwinian fitness of various traits changes with it. Thus by his own efforts man is continually altering the selective pressure for or against certain genes.

The most obvious example, and one with disturbing overtones, is to be found in the advance of medicine and public health. Retinoblastoma, the eye cancer of children, is almost always fatal if it is not treated. Here is "natural" selection at its most rigorous, weeding out virtually all of the harmful mutant genes



CHEMICAL STRUCTURE OF HEMOGLOBIN in an individual's blood is determined by his genes. Normal and abnormal hemoglobins move at different speeds in an electric field. This photograph, made by Henry G. Kunkel of the Rockefeller Institute, shows surface of a slab of moist starch on which samples of four kinds of human hemoglobin were lined up at top, between a negative electrode at top and a positive electrode at bottom (electrodes are not shown). When current was turned on, the samples migrated toward positive electrode. At right hemoglobin C, the cause of a rare hereditary anemia, has moved down only a short way. Second from right is hemoglobin S, the cause of sickle-cell anemia, which has moved farther in same length of time. Normal hemoglobin, third from right, has separated into its A and A_2 constituents. At left is normal fetal hemoglobin F, obtained from an umbilical cord.

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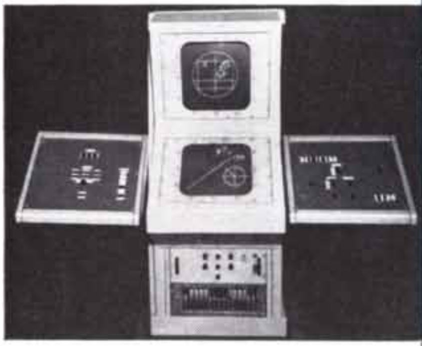

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before they can be passed on even once. With proper treatment, however, almost 70 per cent of the carriers of the gene for retinoblastoma survive, become able to reproduce and therefore to transmit the defect to half their children.

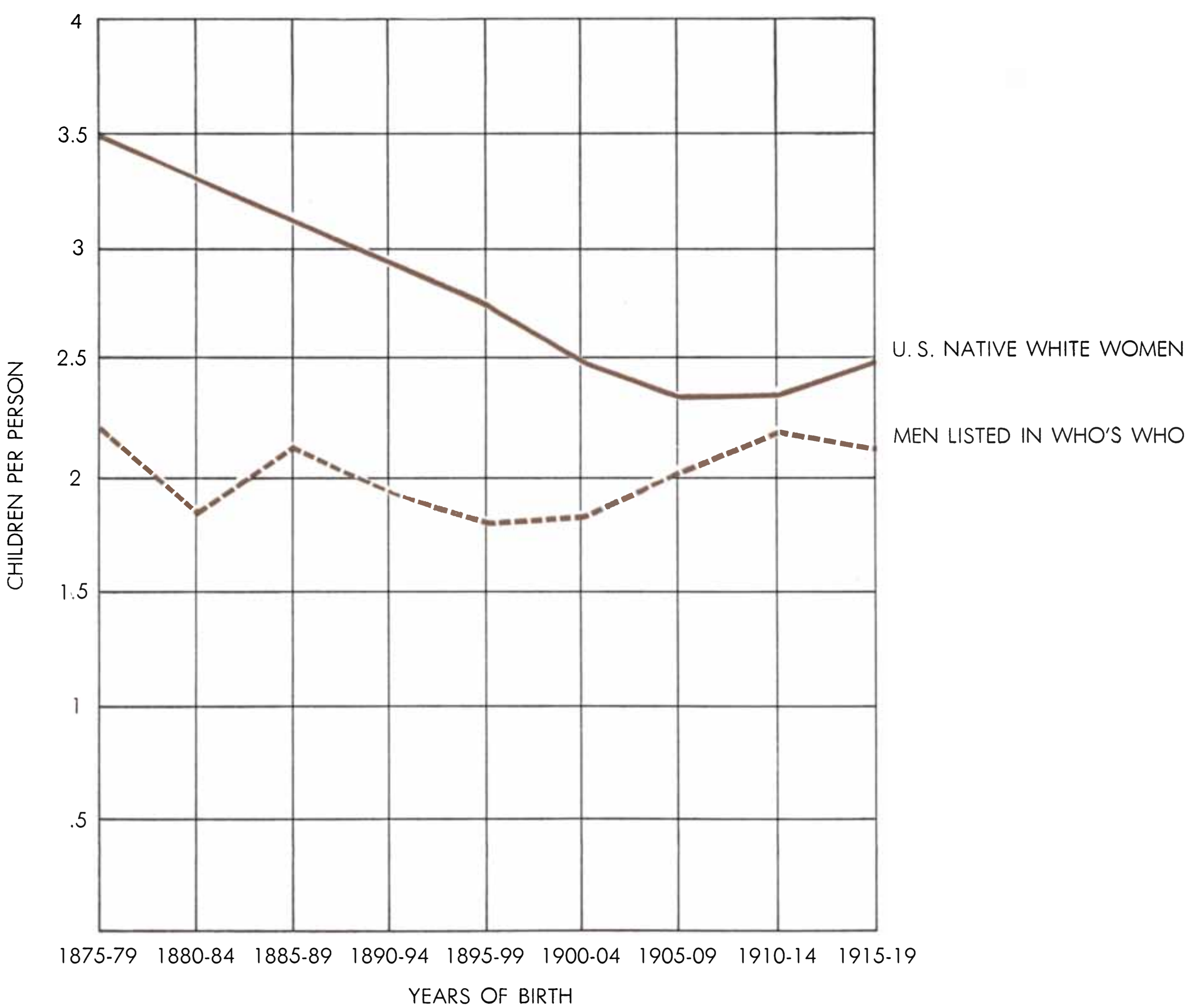
More dramatic, if genetically less clear-cut, instances are afforded by advances in the control of tuberculosis and malaria. A century ago the annual death rate from tuberculosis in industrially advanced countries was close to 500 per 100,000. Improvement in living conditions and, more recently, the advent of antibiotic drugs have reduced the death rate to 7.5 per 100,000 in the U. S. today. A similarly steep decline is under way in the mortality from malaria, which used to afflict a seventh of the earth's population.

Being infectious, tuberculosis and malaria are hazards of the environment. There is good evidence, however, that individual susceptibility, both as to contracting the infection and as to the severity of the disease, is genetically conditioned. (We have already mentioned the protective effect of the gene for sickle-cell anemia. This is probably only one of several forms of genetic resistance to malaria.) As the prevalence of these diseases decreases, so does the threat to susceptible individuals. In other words, the Darwinian fitness of such individuals has increased.

It was pointed out earlier that one effect of civilization is to increase mutation rates and hence the supply of harmful genes. A second effect is to decrease the rate of discrimination against such genes, and consequently the rate of their elimination from human populations by natural selection. In thus disturbing the former genetic equilibrium of inflow and outflow, is man not frustrating natural selection and polluting his genetic pool?

The danger exists and cannot be ignored. But in the present state of knowledge the problem is tremendously complex. If our culture has an ideal, it is the sacredness of human life. A society that refused, on eugenic grounds, to cure children of retinoblastoma would, in our eyes, lose more by moral degradation than it gained genetically. Not so easy, however, is the question whether a person who knows he carries the gene for retinoblastoma, or a similarly deleterious gene, has a right to have children.

Even here the genetic issue is clear, although the moral issue may not be. This is no longer true when we come to genes that are harmful in double dose,



FERTILITY RATE among relatively intelligent people, as represented by a random sample of men listed in *Who's Who in America* for 1956 and 1957, is lower than fertility rate of the U. S. population as a whole, as represented by all native white women. The two fertility rates have recently been moving toward each other. Vertical scale shows average number of children per person; horizontal scale shows approximate birth date of parents. Chart is based upon information collected by Dudley Kirk of the Population Council.

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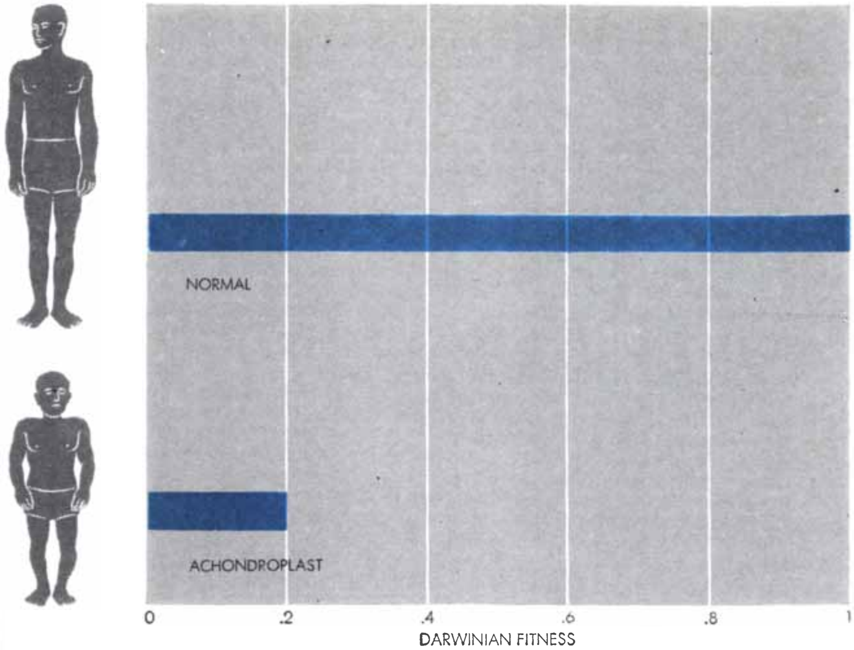


DARWINIAN FITNESS of achondroplastic dwarfs is low. Dwarfs may be healthy, but they have only 20 surviving children to every 100 surviving children of normal parents.

but beneficial in single. If the central African peoples had decided some time ago to breed out the sickle-cell gene, they might have succumbed in much larger numbers to malaria. Fortunately this particular dilemma has been resolved by successful methods of mosquito control. How many other hereditary diseases and malformations are maintained by the advantages their genes confer in heterozygous carriers, we simply do not know.

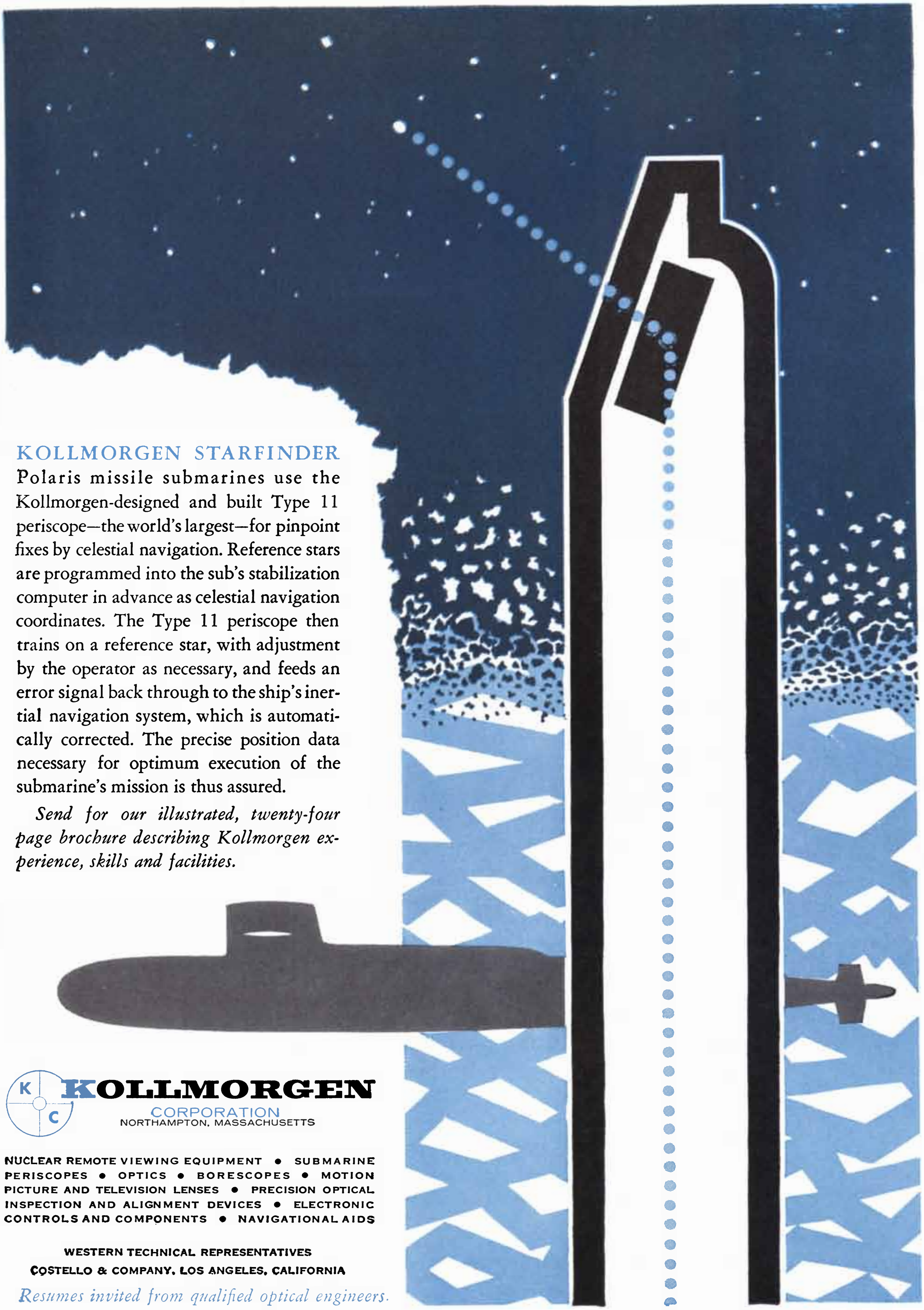
Conversely, we cannot yet predict the genetic effect of relaxing selection pressure. If, for example, susceptibility to tuberculosis is maintained by recurrent mutations, then the conquest of the disease should increase the concentration of mutant genes as time goes on. On the other hand, if resistance arises from a single dose of genes that make for susceptibility in the double dose, the effects of eradication become much less clear. Other selective forces might then determine the fate of these genes in the population.

In any case, although we cannot see all the consequences, we can be sure that ancient genetic patterns will continue to shift under the shelter of modern medicine. We would not wish it otherwise. It may well be, however, that the social cost of maintaining some genetic variants will be so great that artificial selection against them is ethically, as well as economically, the most acceptable and wisest solution.

If the evolutionary impact of such biological tools as antibiotics and vaccines is still unclear, then computers and rockets, to say nothing of social organizations as a whole, present an even deeper puzzle. There is no doubt that human survival will continue to depend more and more on human intellect and technology. It is idle to argue whether this is good or bad. The point of no return was passed long ago, before anyone knew it was happening.

But to grant that the situation is inevitable is not to ignore the problems it raises. Selection in modern societies does not always encourage characteristics that we regard as desirable. Let us consider one example. Much has been written about the differential fertility that in advanced human societies favors less intelligent over more intelligent people. Studies in several countries have shown that school children from large families tend to score lower on so-called intelligence tests than their classmates with few or no brothers and sisters. Moreover, parents who score lower on these tests have more children on the average than those who get higher marks.

We cannot put our finger on the forces responsible for this presumed selection against intelligence. As a matter of fact, there is some evidence that matters are changing, in the U. S. at least. People included in *Who's Who in America* (assuming that people listed in this directory are on the average more intelligent



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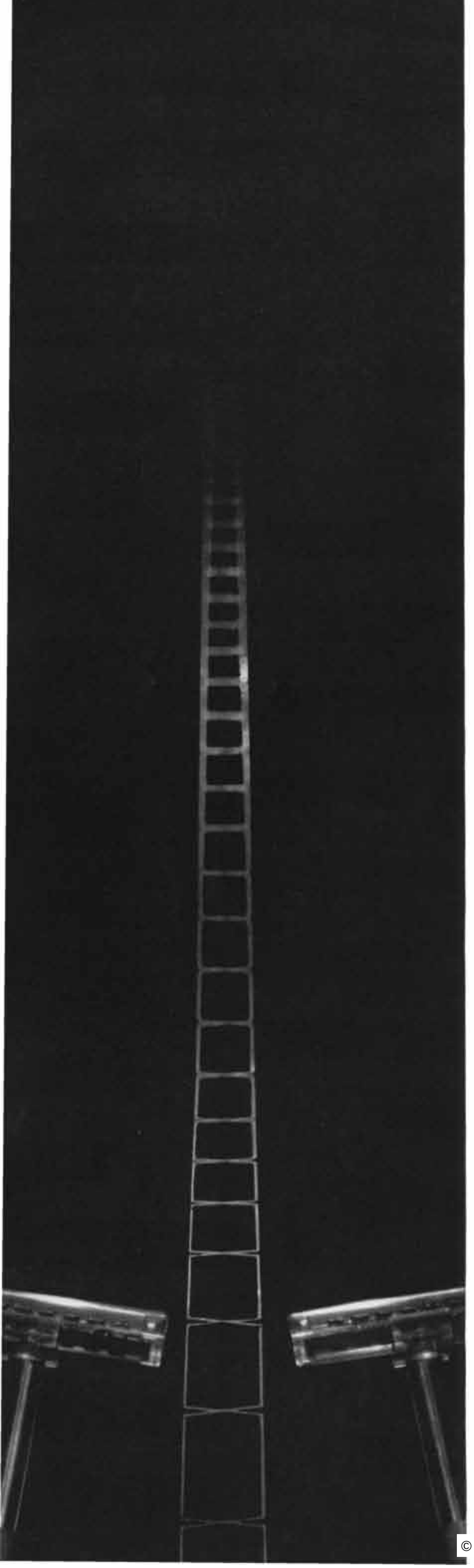

The Case for the Terrestrial Traveler

Figure that every thirteen seconds American drivers motor 238,000 miles — the distance to the moon. Increasing the efficiency, comfort, and safety of this incredible private transportation system (60 million cars!) is a top project goal of the General Motors Research Laboratories. From this sizable R & D program have already come a number of experimental controls and driver aids now being evaluated in the field.

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General Motors Research Laboratories
Warren, Michigan

Car pickup coils and road wiring used for guidance and speed control in one experimental automatic highway system under study.

than people not listed there) had fewer children than the general population during the period from 1875 to 1904. In the next two decades, however, the difference seemed to be disappearing. L. S. Penrose of University College London, one of the outstanding human geneticists, has pointed out that a negative correlation between intelligence and family size may in part be corrected by the relative infertility of low-grade mental defectives. He suggests that selection may thus be working toward maintaining a constant level of genetic conditioning for intelligence in human populations. The evidence presently available is insufficient either to prove or to contradict this hypothesis.

It must also be recognized that in man and other social animals qualities making for successful individuals are not necessarily those most useful to the society as a whole. If there were a gene for altruism, natural selection might well discriminate against it on the individual level, but favor it on the population level. In that case the fate of the gene would be hard to predict.

If this article has asked many more questions than it has answered, the purpose is to suggest that answers be sought with all possible speed. Natural selection is a very remarkable phenomenon. But it does not even guarantee the survival of a species. Most living forms have become extinct without the "softening" influence of civilization, simply by becoming too narrowly specialized. Natural selection is opportunistic; in shaping an organism to fit its surroundings it may leave the organism unable to cope with a change in environment. In this light, man's explosive ability to change his environment may offer as much threat as promise. Technological evolution may have outstripped biological evolution.

Yet man is the only product of biological evolution who knows that he has evolved and is evolving further. He should be able to replace the blind force of natural selection by conscious direction, based on his knowledge of nature and on his values. It is as certain that such direction will be needed as it is questionable whether man is ready to provide it. He is unready because his knowledge of his own nature and its evolution is insufficient; because a vast majority of people are unaware of the necessity of facing the problem; and because there is so wide a gap between the way people actually live and the values and ideals to which they pay lip service.

MATHEMATICAL GAMES

The celebrated four-color map problem of topology

by Martin Gardner

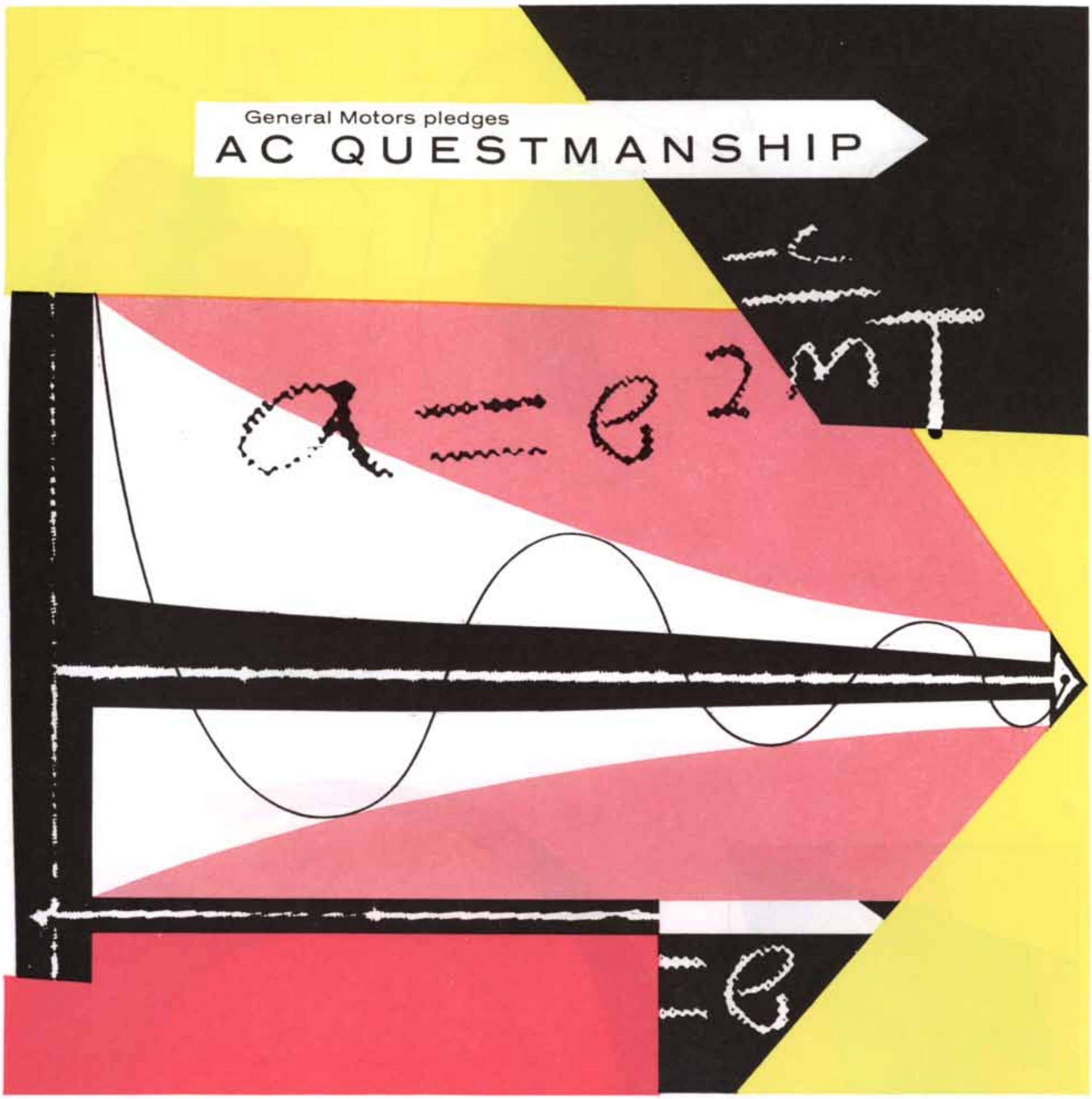
Of all the great unproved conjectures of mathematics the simplest —simple in the sense that a small child can understand it—is the famous four-color theorem of topology. How many colors are needed for coloring any map so that no two countries with a common border will have the same color? It is easy to construct maps that require four colors, and only a knowledge of elementary mathematics is required to follow a rigorous proof that five colors are sufficient. But are four colors both necessary and sufficient? To put it another way, is it possible to construct a map that will require five colors? Mathematicians who are interested in the matter think not, but they are not sure.

Every few months I receive in the mail a lengthy "proof" of the four-color theorem. In almost every case it turns out that the sender has confused the theorem with a much simpler one which states that it is impossible to draw a map of five regions in such a way that each region is adjacent to the other four. (Two regions that meet at a single point are not considered adjacent.) I myself contributed in a small way to this confusion by once writing a science-fiction story entitled "The Island of Five Colors," about an imaginary island divided by a Polish topologist into five regions that all had common borders. (The story was recently reprinted in Clifton Fadiman's anthology *Fantasia Mathematica.*) It is not difficult to prove that a map of this sort cannot be drawn. One might suppose that the four-color theorem for all maps would now follow automatically, but such is not the case.

To see why this is so, consider the simple map at *a* in the illustration at the top of page 220. (The actual shapes of the regions do not matter; only the manner in which they are connected is significant. The four-color theorem is topological precisely because it deals with a property of plane figures that is unaltered by distorting the surface on which they are inscribed.) What color shall we use for the blank region? Obviously we must color it either red or a fourth color. Suppose we take the second alternative and color it green, as shown at *b* in the illustration. Then we add another region. It is now impossible to complete the map without using a fifth color. Let us go back, then, to *a*, and instead of putting green for the blank region, use red. But this gets us into difficulty if two more regions touch the first four, as shown at *c*. Clearly fourth and fifth colors are necessary for the two blank areas. Does all this prove that five colors are necessary for some maps? Not at all. In both cases we can manage with four colors, but only by going back and altering the previous color scheme.

In coloring complicated maps, with dozens of regions, we find ourselves constantly running into blind alleys of this sort that require a retracing of steps. To prove the four-color theorem, therefore, one must show that in all cases such alterations can always be made successfully, or devise a procedure that will eliminate all such alterations in the process of coloring any map with four colors. Stephen Barr of Woodstock, N.Y., has suggested a delightful two-person topological game that is based on the difficulty of foreseeing these color *cul-de-sacs.* Player A draws a region. Player B colors it and adds a new region. Player A colors the new region and adds a third. This continues, with each player coloring the last region drawn by his opponent, until a player loses the game by being forced to use a fifth color. I know of no quicker way to recognize the difficulties involved in proving the four-color theorem than to engage in this curious game.

The four-color theorem has long been familiar to map makers, but it seems to have first been mentioned as a mathematical problem in an 1840 lecture by August Ferdinand Moebius, the German astronomer for whom the well-known Moebius strip is named. In 1879 the British lawyer and mathematician Sir Alfred Kempe published what he be-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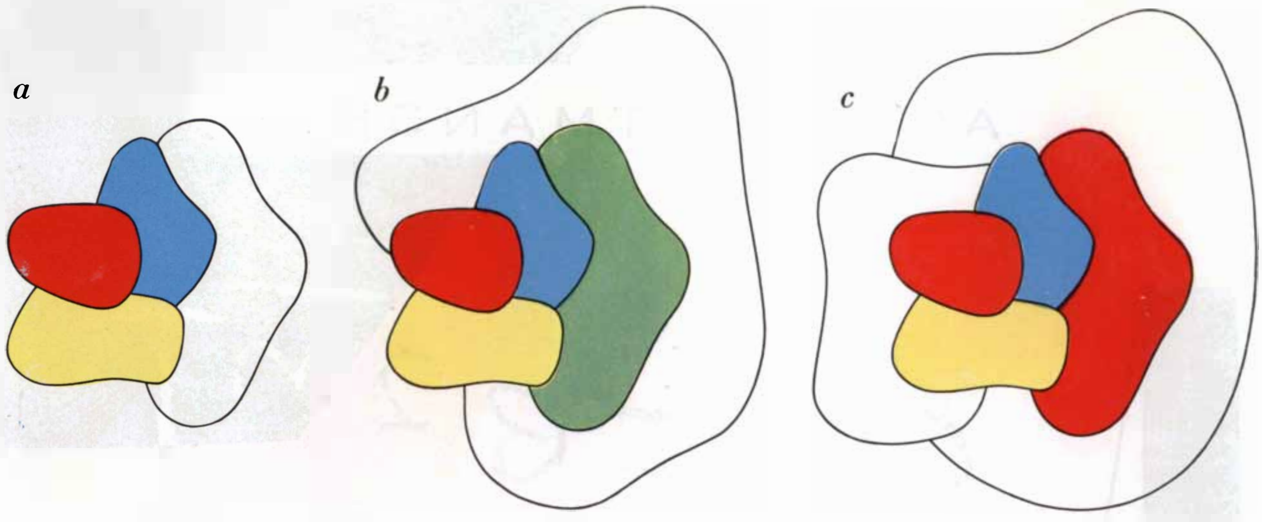
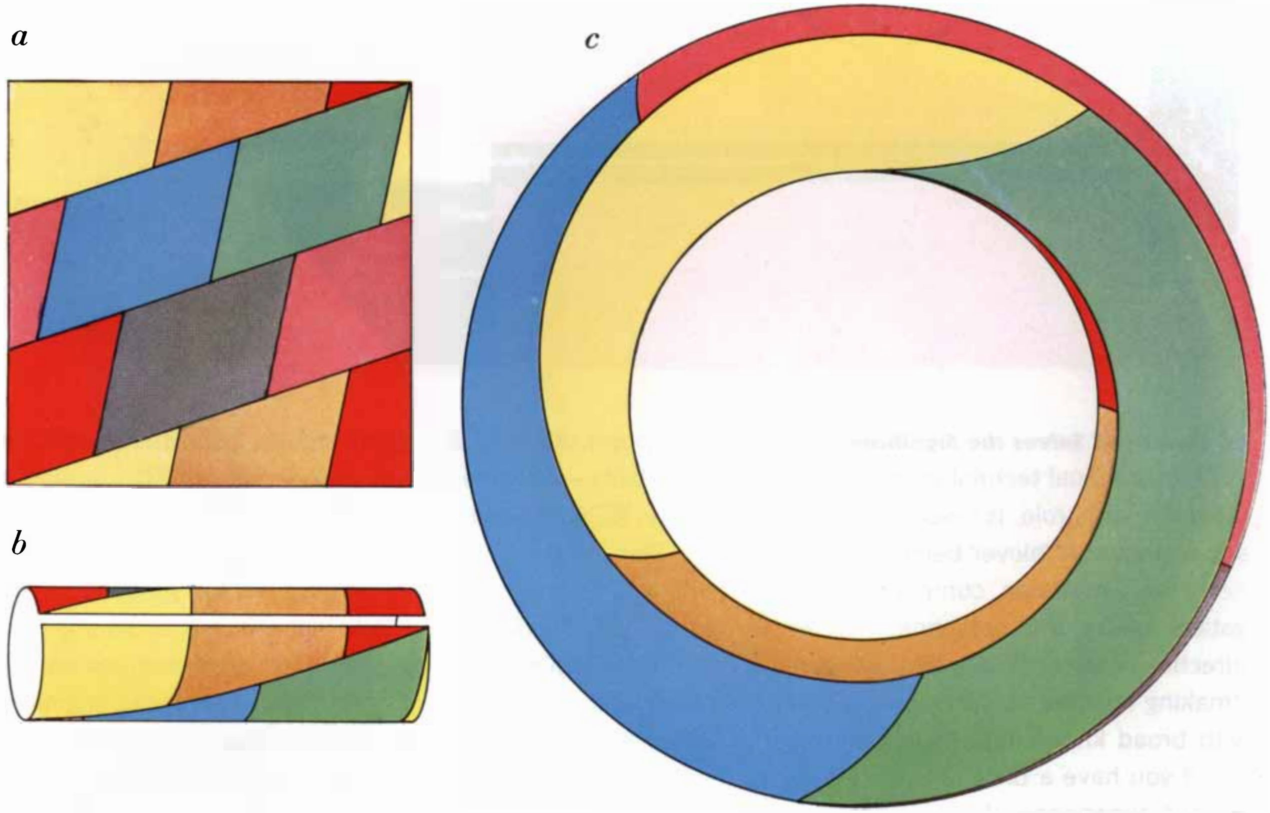


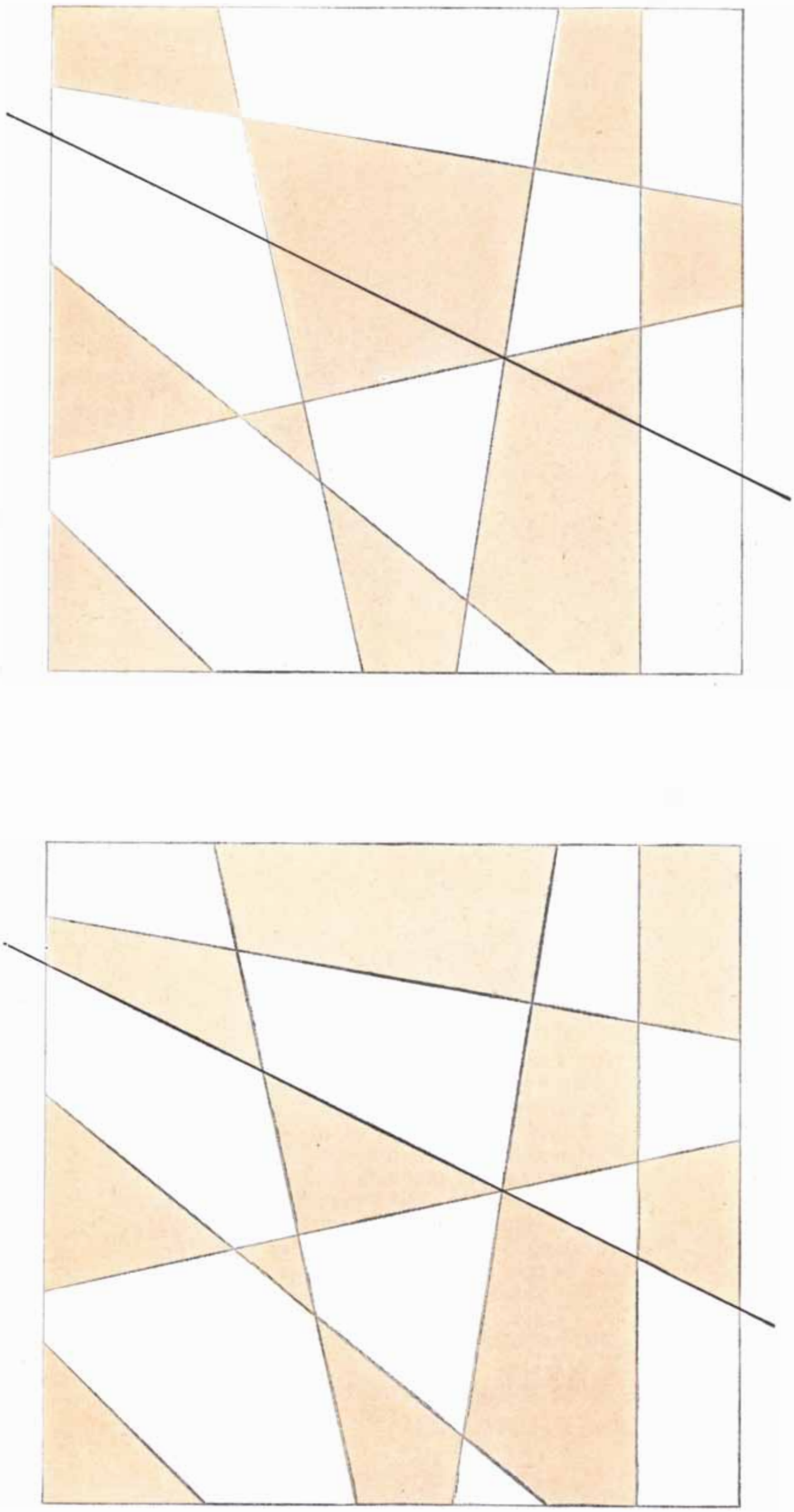
In making a map with four colors it is often necessary to start over again with different colors



Seven colors make a map on a torus (c). The sheet (a) is first rolled into a cylinder (b). The resulting torus is enlarged lieved to be a proof, and a year later he contributed to the British journal *Nature* an article with the overconfident title "How to Colour a Map with Four Colours." For 10 years mathematicians thought the problem had been disposed of; then P. J. Heawood spotted a fatal flaw in Kempe's proof. Since that time the finest minds in mathematics have grappled unsuccessfully with the problem. The tantalizing thing about the theorem is that it *looks* as though it should be quite easy to prove. In his autobiographical book *Ex-Prodigy* Norbert Wiener writes that he has tried, like all mathematicians, to find a proof of the four-color theorem, only to find his proof crumble, as he expresses it, to fool's gold in his hands. As matters now stand, the theorem has been established for all maps with no more than 37 regions. This may seem like a small number, but it becomes less trivial when we realize that the number of topologically different maps with 37 or less regions would run to more than 10^{37}. Even a modern electronic computer would not be able to examine all these configurations in a reasonable length of time.

The lack of proof for the four-color theorem is made even more exasperating by the fact that analogous proofs have been found for surfaces much more complicated than the plane! (The surface of a sphere, by the way, is the same as a plane so far as this problem goes; any map on the sphere can be transformed to an equivalent plane map by puncturing the map inside any region and then flattening the surface.) On one-sided surfaces such as the Moebius strip, the Klein bottle and the projective plane it has been established that six colors are necessary and sufficient. On the surface of the torus, or anchor ring, the number is seven. Such a map is shown in the illustration at the bottom of the opposite page. Note that each region is bounded by six line segments and that every region is adjacent to the other six. In fact, the map-coloring problem has been solved for every higher surface that has been seriously investigated. The problem is trivial when applied to figures of more than two dimensions, because in all higher dimensions the number of colors required is infinite. In three dimensions, for example, any number of colored ropes can be braided together so that any two of the ropes touch along a portion of their surfaces.

It is only when the theorem is applied to surfaces topologically equivalent to a plane or surface of a sphere that its proof continues to frustrate topologists; and



Two colors suffice for any map drawn with lines that cut across the entire surface

what is worse still, there is no apparent reason why this should be so. There is something spooky about the way in which attempted proofs seem to be working out beautifully, only to develop an infuriating gap just as the deductive chain is about to be completed. No one can predict what the future will decide about this famous problem, but we can be sure that world fame awaits the first person who achieves one of three possible break-throughs:

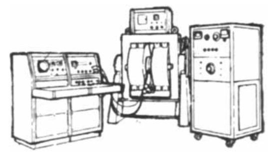
1. A map requiring five colors will be discovered. "If I be so bold as to make a conjecture," writes H. S. M. Coxeter in his excellent article "The Four-Color Map Problem, 1840-1890" (*The Mathematics Teacher;* April, 1959), "I would guess that a map requiring five colors may be possible, but that the simplest such map has so many faces (maybe hundreds or thousands) that nobody, confronted with it, would have the patience to make all the necessary tests that would be required to exclude the possibility of coloring it with four colors."

2. A proof of the theorem will be found, possibly by a new technique that may suddenly unlock many another bolted door of mathematics.

3. The theorem will be proved impossible to prove. This may sound strange, but in 1931 Kurt Gödel established that outside every deductive system there are mathematical theorems that are "undecidable" within the system [see "Gödel's Proof," by Ernest Nagel and James R. Newman; Scientific American, June, 1956]. So far none of the great unsolved conjectures of mathematics has been shown to be undecidable in this sense. Is the four-color theorem such a theorem? If so, then it can be accepted as "true" only by adopting it, or some other undecidable theorem closely linked to it, as a new and unprovable postulate of an enlarged deductive system.

Unfortunately the proof that five colors are sufficient for plane maps, or that six or more colors are necessary and sufficient for certain higher surfaces, is too lengthy to include here. But perhaps the following clever proof of a two-color theorem will give the reader some notion of how one can go about establishing a map-coloring theorem.

Let us consider all possible maps on the plane that can be formed by straight lines. The ordinary checkerboard is a familiar example. A less regular pattern is shown in the top illustration at left, and it is easy to see that, as in the checkerboard, two colors are sufficient for coloring it. Are two colors sufficient for all such maps? The answer is yes, and it is



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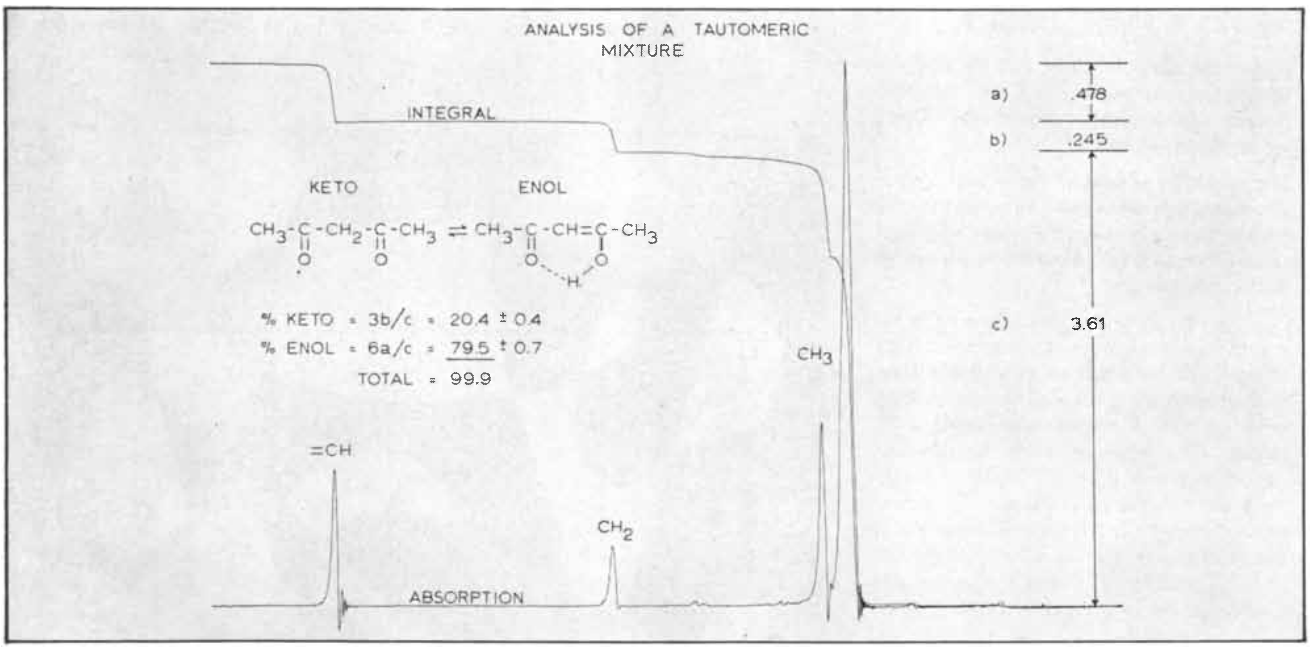
AN EXAMPLE: *Analysis of a tautomeric mixture*



A particularly difficult analysis from a chemical point of view is the tautomeric mixture of *keto* and *enol* forms of acetyl acetone which are in rapid equilibrium with one another. The area of the olefinic proton peak, which is proportional to the amount of *enol*, can be compared with the total methyl absorption due to both species to give 79.5 percent *enol*. Similarly, the CH_2 resonance of the *keto* form gives 20.4 percent *keto*. The accuracy of the determination is checked by the fact that the sum of *keto* and *enol* calculated independently in this way gives 99.9 percent.

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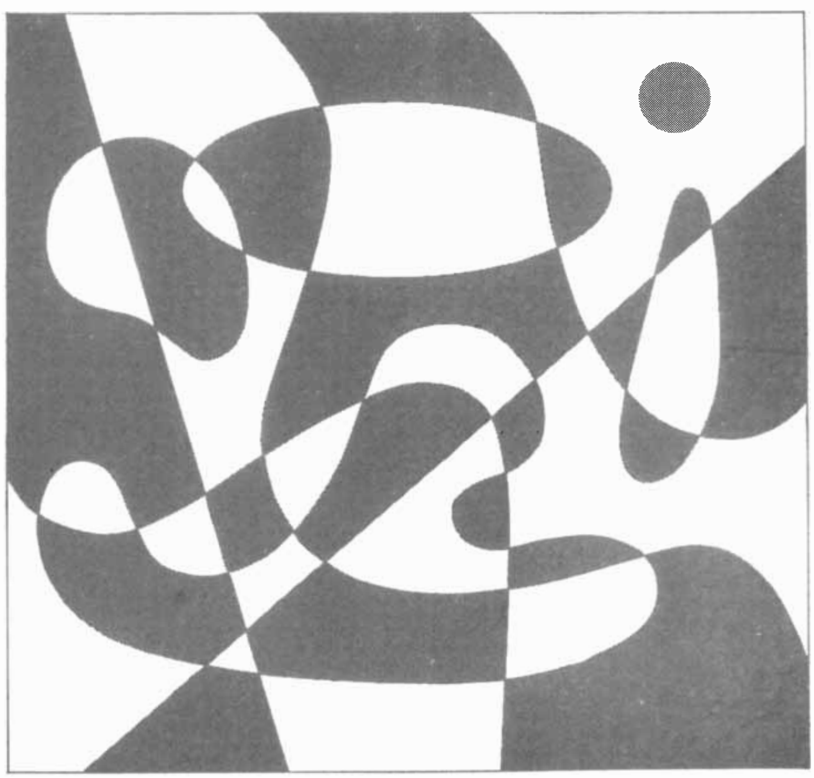
To complete the proof, consider a plane that is divided into two regions by a single line. It can of course be constructed with two colors. We draw a second line and recolor the new map by reversing the colors on one side of the line. We draw a third line, and so on. Clearly this procedure will work for any number of lines, so by a method known as "mathematical induction" we have established the two-color theorems for all possible maps drawn with straight lines. The proof can be generalized to cover less rigid maps, such as the one in the illustration on this page, which are drawn with endless lines that either cut across the entire map or lie on it as simple closed curves. If we add a line that crosses the map, we reverse the colors on one side of the line as before. If the new line is a closed curve, we reverse the colors of all regions inside the curve or, if we prefer, the colors of regions outside the curve. The closed curves may also intersect themselves, but then the recoloring procedure becomes more complicated.

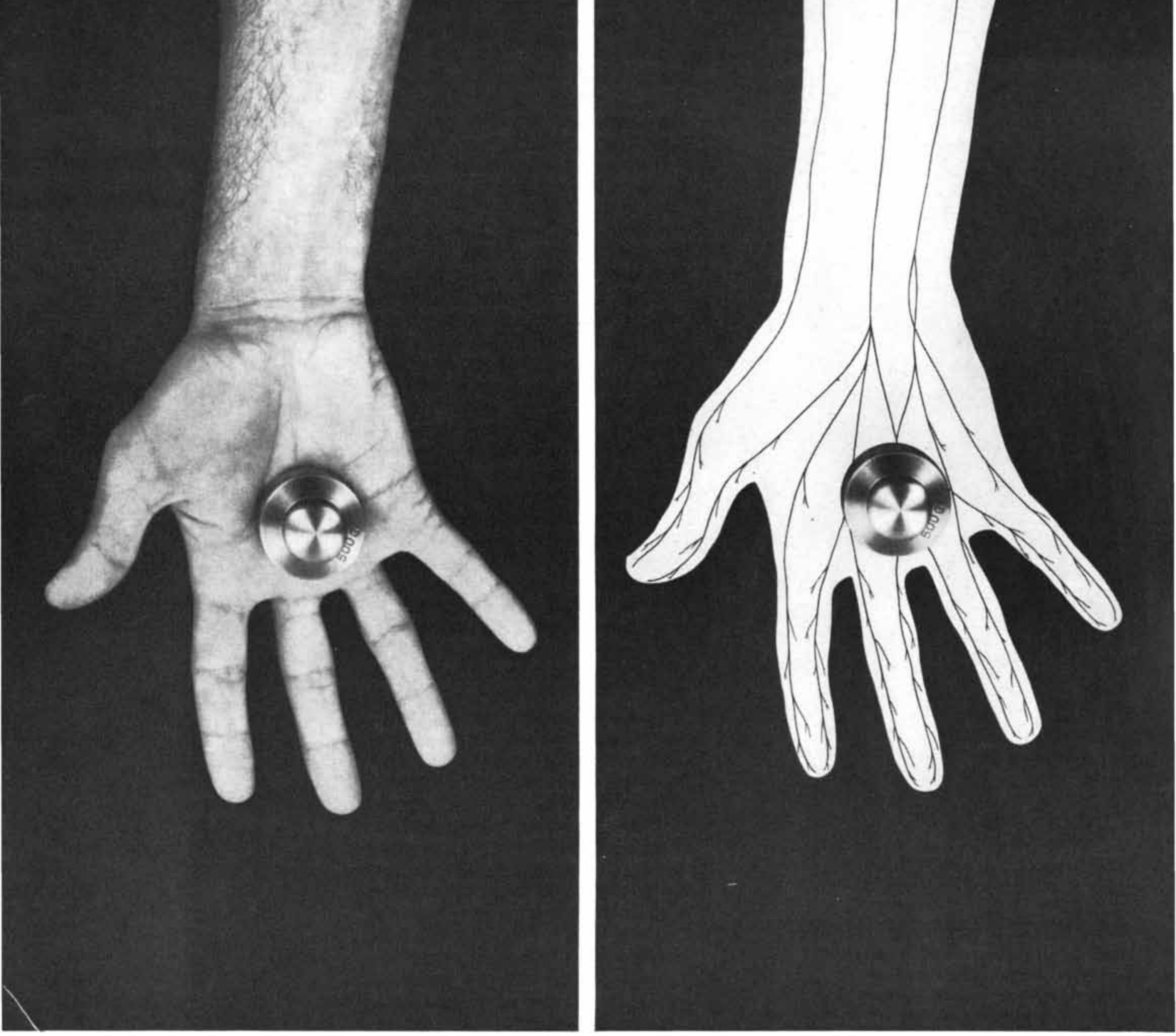
Now, more for amusement than for enlightenment, here are three map-coloring problems that are not difficult, although each has a "catch" element of some sort that makes the solution not quite what one would at first expect:

1. How many colors are required for the map at the top of page 226 (devised by the English puzzlist Henry Ernest Dudeney), so that no two regions of the same color border on each other?

2. Stephen Barr writes about the painter who wished to complete on a huge canvas the nonobjective work of art shown in outline at the bottom of page 226. He decided to limit himself to four colors, and to fill each region with one solid color in such a way that there would be a different color on each side of every common border. Each region had an area of eight square feet, except for the top region, which was twice the size



Two colors also suffice for a map drawn with lines that either cut across or form closed curves



The relationship between subjective sensations (left) and the corresponding codes of the nervous system (right) are now under study at IBM.

Comparing human sensations and their related nerve signals

What is the relationship of a man judging the amount of pressure on his skin and a physiologist measuring the firing rate in animal nerves? The first is a subjective, or *psycho*physical measurement, while the second is *neuro*physiological. To find the relationship between these two kinds of measurements, they would have to be made on the same subject.

Recently developed techniques have now made this possible. At IBM Research, physiological psychologists measure nerve signals through simple contacts applied to human subjects. A stimulus is applied and the neural signals are recorded. Interfering responses are separated from test responses using a computer programmed to measure the systematic neural signals. Since the subjects can also describe the sensations produced, a direct comparison can be made.

In this way, IBM psychologists are learning more about the complex codes by which the neural network evokes the myriad sensations of human experience. Their eventual aim is to unravel the coding pattern from the stimulus input through the peripheral nerves to the brain and the sensations reported by the subjects.

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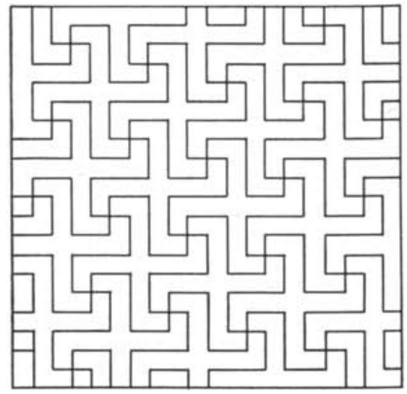
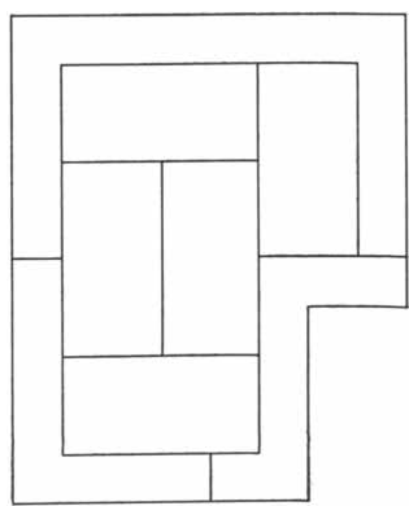


How many colors are needed for this map?

of the others. When he checked his paint supplies, he found that he had on hand only the following: enough red to cover 24 square feet, enough yellow to cover the same area, enough green to cover 16 square feet and enough blue to paint eight square feet. How did he manage to complete his canvas?

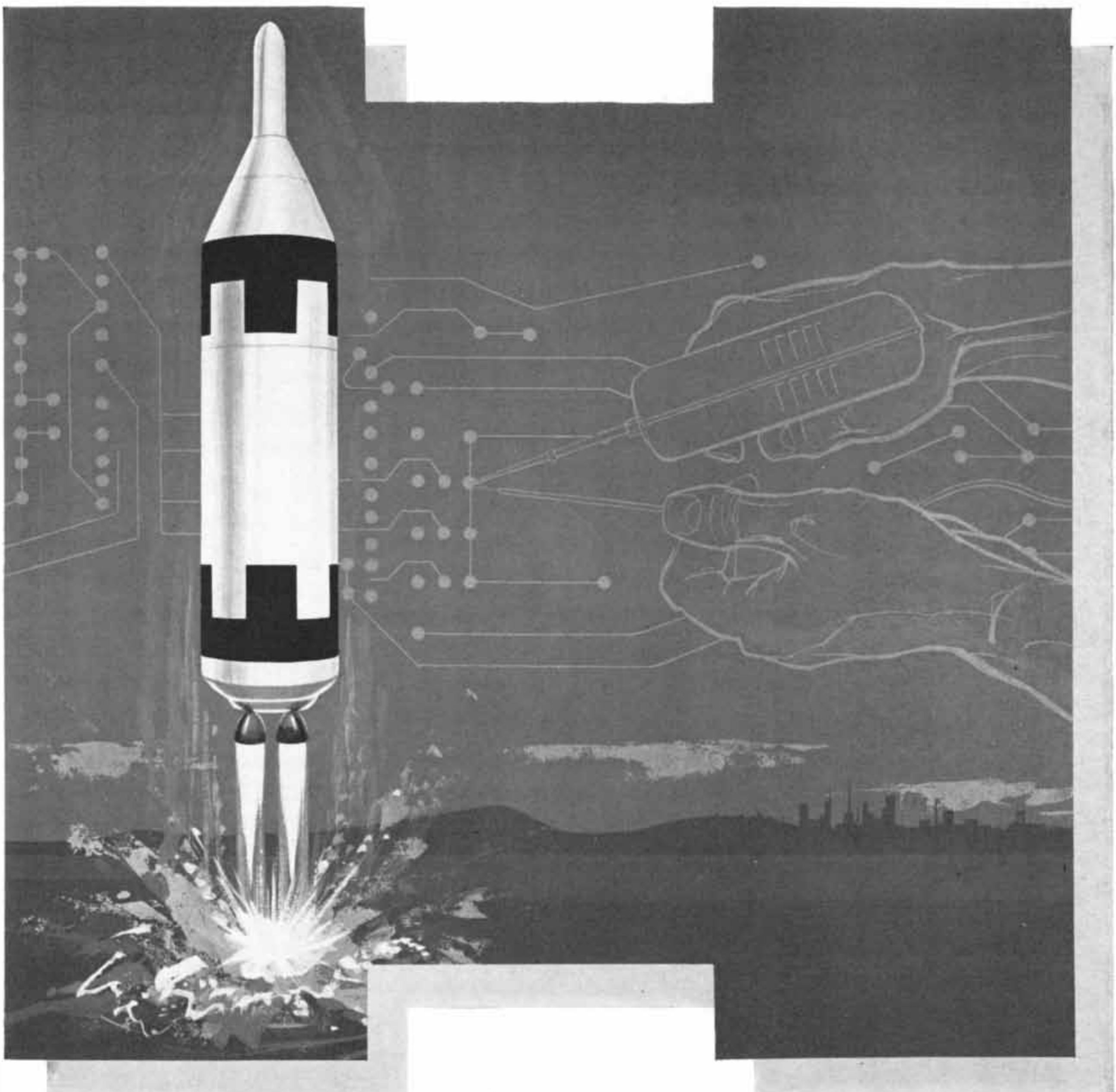
3. Leo Moser, a mathematician at the University of Alberta, passes on this intriguing question. How can a two-color map be drawn on a plane so that no matter where you place on it an equilateral triangle with a side of 1, all three vertices never lie on points of the same color?

Last month's card-shuffled sentence deciphers as: "The smelling organs of fish have evolved in a great variety of forms." It is the first sentence of the last paragraph on page 73 of the article "The Homing Salmon," by Arthur D. Hasler and James A. Larsen, in SCIENTIFIC AMERICAN for August, 1955.



How many are needed for this abstraction?

Putting Polaris on a precision



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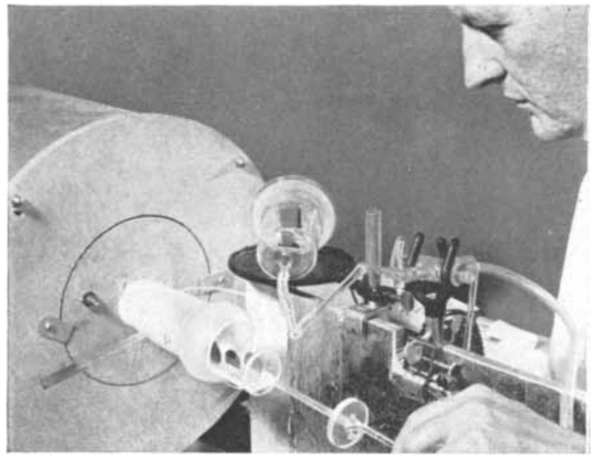

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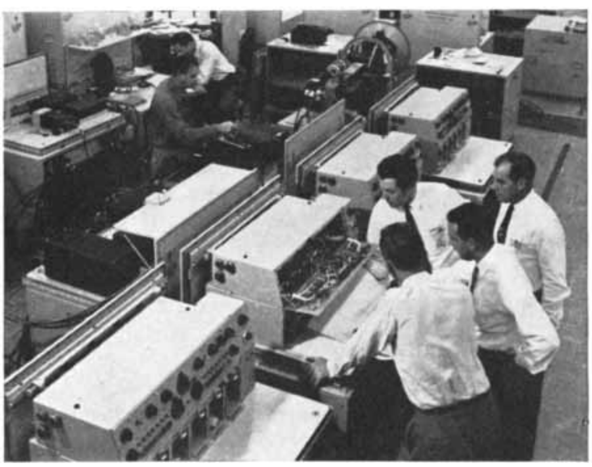

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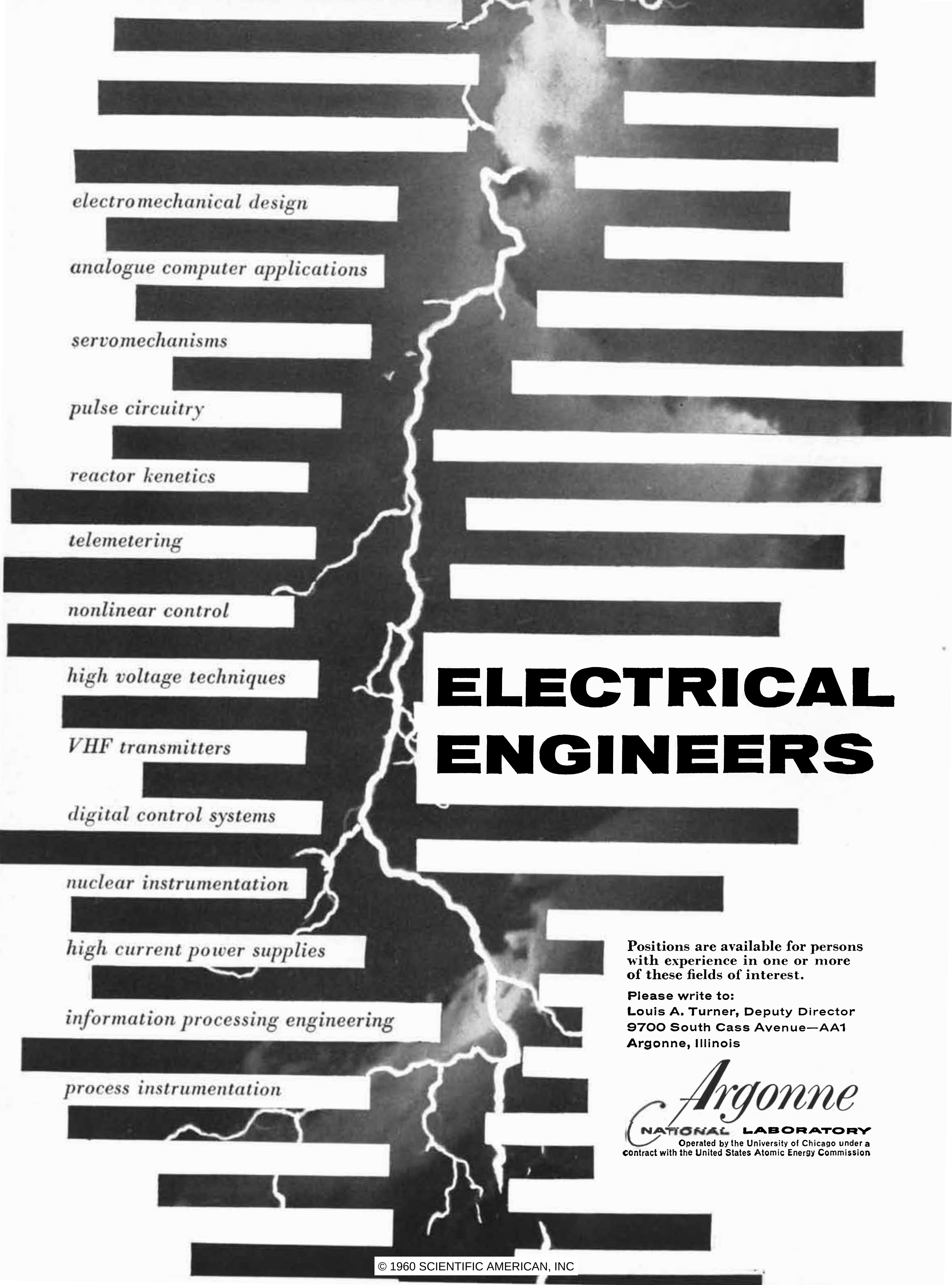
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THE AMATEUR SCIENTIST

How a group of amateurs detected flares on the sun with long-wave radio receivers

Conducted by C. L. Stong

If you could watch the sun through a small telescope continuously for several years, you might eventually see a solar flare, the most violent eruption of energy in our part of the universe. The flare would appear abruptly as a brilliant spot, persist for a few minutes and then fade out.

Only the largest flares could be observed in this way. You can readily detect many smaller flares, however, if you have a radio receiver that can be tuned to very long waves. This part of the radio spectrum is usually quiet during the daylight hours, except, of course, on frequencies used by transmitting stations. During a solar flare the long-wave region crackles with "static" of the sort that we hear on the radio during a thunderstorm. In recent years this upsurge of radio noise has been increasingly used to detect the onset of flares.

David Warshaw of Brooklyn, N.Y., has designed an inexpensive radio receiver expressly for the purpose of monitoring flare activity. When this apparatus became available, a small group of amateurs across the nation volunteered to make a continuous patrol of solar flares as a contribution to the International Geophysical Year. The group's observations are now published regularly in the *Solar-Geophysical Data Bulletin* of the National Bureau of Standards and have been distributed routinely to the IGY World Centers.

The project got under way five years ago when Harry Bondy, chairman of the Solar Division of the American Association of Variable Star Observers, asked Warshaw to copy an elaborate radio receiver that had been designed in England for flare detection. "Our group in the Solar Division of the AAVSO," writes Bondy, "was already providing sunspot observations to the Bureau of Standards for the computation of the so-called American Relative Sunspot Number, an index of solar activity that is useful in making long-range predictions of ionospheric conditions, and is consequently of interest to the communications industry. The results of this work had been well received in geophysical circles, so we were on the lookout for a project that would enable us to participate in the IGY, which was then in the planning stage. One of the programs under consideration for the IGY was the study of solar flares. This program appeared to hold little promise for us, because at that time the observation of all but the most intense flares required costly spectrohelioscopes or monochromators, instruments sensitive to certain wavelengths of light emitted by flares. A few enthusiasts, including Walter J. Semerau of Kenmore, N.Y., and David Warshaw had built such instruments [see "The Amateur Scientist," April, 1958], but the equipment was beyond the reach of most amateurs.

"Then, in the summer of 1955, I received a mimeographed circular from the U. S. National Committee for the IGY: 'The Recording of Sudden Enhancements of Atmospherics (SEA) for Purposes of Flare Patrol,' by M. A. Ellison, then astronomer of the Royal Observatory at Edinburgh. The circular explained how X-rays and ultraviolet rays emitted by a flare cause a large increase in the number of free electrons in the ionosphere at heights from 60 to 90 kilometers, and how this effect, in turn, greatly enhances the reflection of very long radio waves that obliquely strike the lowest of the ionosphere's four layers: the so-called D layer. A proportional enhancement is simultaneously observed in the strength of radio signals received from a distant source after one or more reflections from the ionosphere.

"According to Ellison, the effect was first described by the French physicist R. Bureau, who investigated the enhancement of signals by recording the integrated level of tropical thunderstorm atmospherics at many different wavelengths. He found that sudden enhancements of atmospherics, or 'SEAs,' are characteristic of the spectral range from 7,000 to 16,000 meters, being most pronounced at the wavelength of 11,000 meters (27 kilocycles). There is no question, Ellison wrote, 'of an increase in the number of atmospherics at such times; the phenomenon is simply one of improved propagation at these wavelengths. The reflections take place during the daylight hours from a height of about 75 kilometers, and typical SEAs have never been observed outside the illuminated hemisphere.'

"I gathered from Ellison's lucid description of the apparatus that a station for recording SEAs would be simple and inexpensive to build. Even so, I did not feel competent to undertake the construction. My interests incline mostly toward the analysis of data, and I feel distinctly uncomfortable in the presence of pliers and soldering irons. Our group includes several radio 'hams,' however, and I hoped that I could persuade them to set up a network of SEA stations and turn their recordings over to me.

"At about this time Warshaw, who is a member of our group and an electronics specialist in the communications industry, invited me to accompany him on a tour of a solar observatory on Long Island. During the trip I brought up the subject of recording SEAs. He was immediately fascinated and promised to construct a station as soon as I could supply detailed information to him. I still have the note handed to me by my wife one evening a few weeks later: 'November 8, 1955. David Warshaw telephoned. He is building a 27 k.c. receiver.'

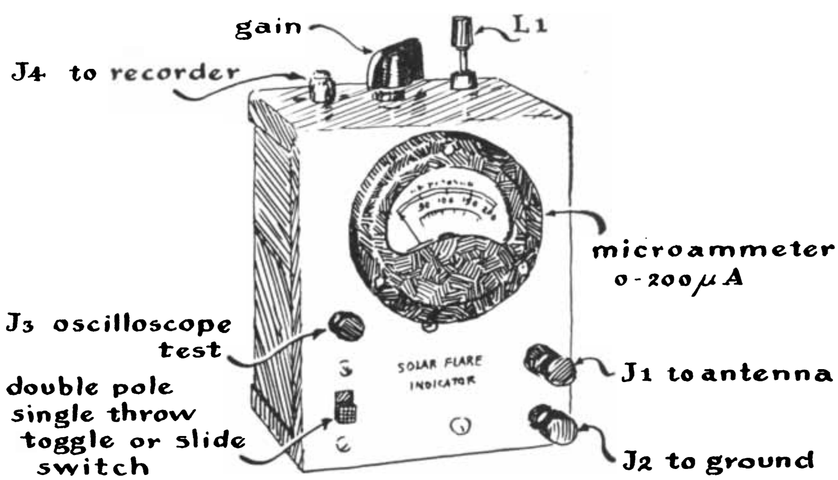
"Dave finished the receiver in about two weeks. Although it performed well, the design proved to be impractical for amateur use. The original circuit called for costly British vacuum tubes and included a number of intricate biasing and voltage-regulating components to keep the indicating meter from fluctuating excessively during heavy signal bursts. After a short trial Warshaw decided to develop a receiver of his own, utilizing transistors. The power and voltage requirements of the transistor are so low that batteries can be substituted for the conventional rectifier, thus eliminating the need for voltage regulation. The design that eventually emerged from Warshaw's basement workshop calls for only three transistors, a solid-state diode, four coils, six resistors and capacitors, a pair of flashlight batteries and a microammeter. The components cost less than $20. The circuit, including the batteries, is housed in a standard apparatus box measuring only three inches wide, four inches deep and five inches long [*see illustration on this page*]. It is fully self-contained and provides enough output to trip a buzzer alarm and drive a pen recorder.

"Upon being tested, the new receiver exhibited gratifying sensitivity. Flares of average intensity or above tripped the buzzer, and on several occasions Warshaw found it possible to telephone his industrial colleagues that the cause of a current transmission black-out was ionospheric in origin and not an equipment failure. At this time Warshaw did not own a pen recorder and so was relying on the buzzer to signal the onset of flares. The relay that actuated the buzzer was set to respond to all signals above a predetermined energy level. This arrangement quickly proved to be disappointing. The buzzer responded to all sorts of noise, including interference originating in nearby oil burners, television receivers and electric shavers. SEAs differed from the spurious signals only in their rate of growth and decay, that is, in their 'wave' shape. One way to identify them with reasonable certainty is to make a graph of the signal by plotting signal amplitude against time. The method requires an automatic pen recorder.

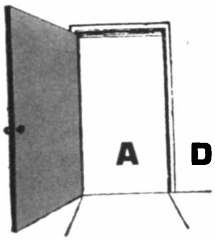
"Warshaw and another member of our group, George Warren of West Chester, Pa., tried to build recorders, but after some weeks they were forced to conclude that such instruments are beyond the resources of most amateurs. Thus the summer of 1956 found us at an impasse. We could neither build a recorder nor afford to buy a commercial instrument. Without demonstrating the effectiveness of Warshaw's receiver, on the other hand, we could not hope to borrow recorders from some interested government group. Then, one day in August, Warshaw located a second-hand recorder within our means—and the next day he picked up a second one! By September he had the first instrument in working order.

"Our first AAVSO Solar Division SEAs Station was now in operation. Up to this point I had acted as little more than a kibitzer. But now I began the analysis of Dave's recordings. I shall never forget the discouragement of those early pen scribbles. The hieroglyphics traced by the 27-kilocycle noise seemed utterly meaningless. The easily distinguished SEAs that stood out so clearly in the published data simply did not appear! Warshaw's station was located in Brooklyn at the intersection of Atlantic Avenue and Flatbush Avenue, where ignition noise is emitted by passing automobiles day and night. He is within half a block of the subway and close to a school that teaches electric welding! Disturbances from these sources appeared at first to mask all other effects.

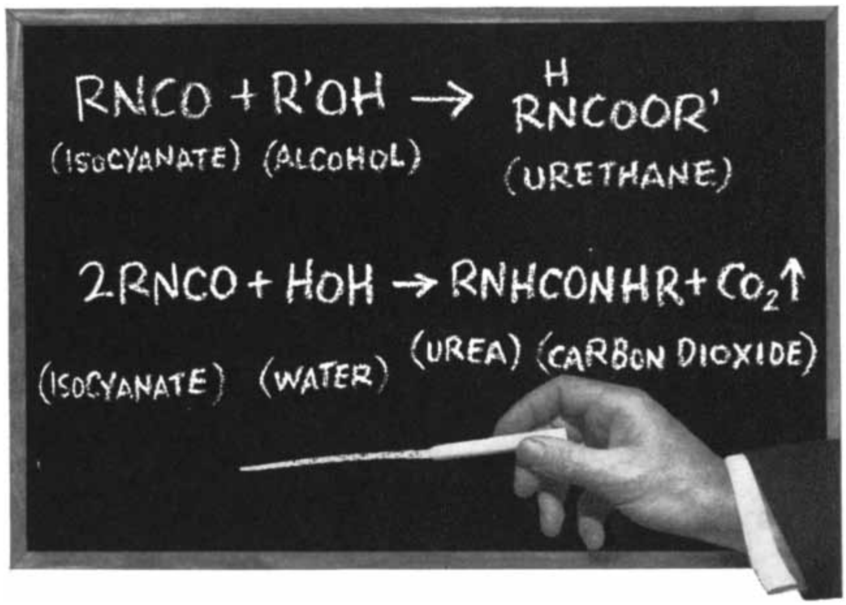
"Warshaw nonetheless persisted. Finally, on October 4, our first 'no-doubt-about-it' SEA appeared on the record. In fact, the tracing for this date displayed three clear flares. These were immediately confirmed by Robert Lee



A receiver for the detection of solar flares (see circuit diagram on page 242)



A DOOR IS OPENED... TO NEW DEVELOPMENTS IN DIISOCYANATES



Key equations of urethane chemistry show the simultaneous reactions of isocyanates with alcohol and with water. The reaction produces a solid product and carbon dioxide, which "blows" the foam material. From "Diisocyanates," a free booklet just off the press.

"Modern chemistry has made few discoveries of greater significance than polymerization. Few polymer formers have greater versatility, actual or potential, than diisocyanates."

This quotation is from a new free booklet prepared by our National Aniline Division. Entitled "Diisocyanates," it describes the origins and development of these polymer formers which are being used to achieve that revolutionary new plastics family, polyurethanes.

Polymeric building blocks

The booklet begins with a discussion of polymers in nature, from which chemists took their cue to devise their own building blocks. One of the most intriguing building blocks for forming large polymer molecules is the class of organic chemicals called diisocyanates. With them it is possible to duplicate the properties of almost all known types of plastics.

In order to help the reader appreciate the diverse materials that can be formed with diisocyanates, the booklet includes a brief history of their origins, followed by an outline of present day chemistry in the field.

Polyurethane foams

From there, the booklet takes us into a discussion of the most interesting and important polyurethanes (polymers based on diisocyanates)—the foams. It tells why and how these materials foam and describes the tremendous variations that are possible. Polyurethane foams range from one to 60 pounds per cubic foot in weight. They can be made rigid enough to support heavy loads or flexible enough to serve as mattresses and coat linings.

Flexible foams

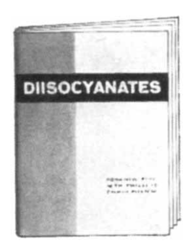
Flexible foams may be produced which have little "bounce-back" and high shock absorbency. These are well adapted to such uses as automobile crash pads, where they minimize the danger of "snapback" injuries, inherent in pads with little absorbency, more bounce. Other flexible foam applications include pillows, furniture cushioning, vermin- and rot-proof carpet underlays, floor mops, clothes brushes, and warm yet lightweight linings for winter clothing.

Rigid foams

You'll read how polyurethanes can be cross-linked to form semi-rigid and rigid foams as well. The former of these can be sprayed onto walls as acoustical insulation or foamed in place in wall cavities where insulation is wanted. Rigid foams find application as harbor buoys, buoyancy chambers for boats, and as filling for aircraft wing tips. You may be surprised to learn that prefabricated sandwich wall panels for homes are now under test and that foamed-in-place polyurethane resins have been used for the setting of bones.

Other polyurethane products

The booklet describes the other forms of polyurethanes as well; for with more cross-links, polyurethanes become plastics that do not warp or swell and have high impact strength. Polyurethane rubbers for example: soles and heels that outlast conventional shoe materials 10 to 1... hundred-thousand-mile tire treads that promise to be a commercial reality soon.



Anyone interested in the general subject of diisocyanate chemistry, or who is working with polyurethane materials, will find the booklet, "Diisocyanates," valuable. *For a free copy,* just write, on company letterhead, to Allied Chemical Corporation, Dept. 96-S, 61 Broadway, New York 6, New York, or phone HAnover 2-7300.

Allied Chemical

BASIC TO AMERICA'S PROGRESS

of the High Altitude Observatory of the University of Colorado.

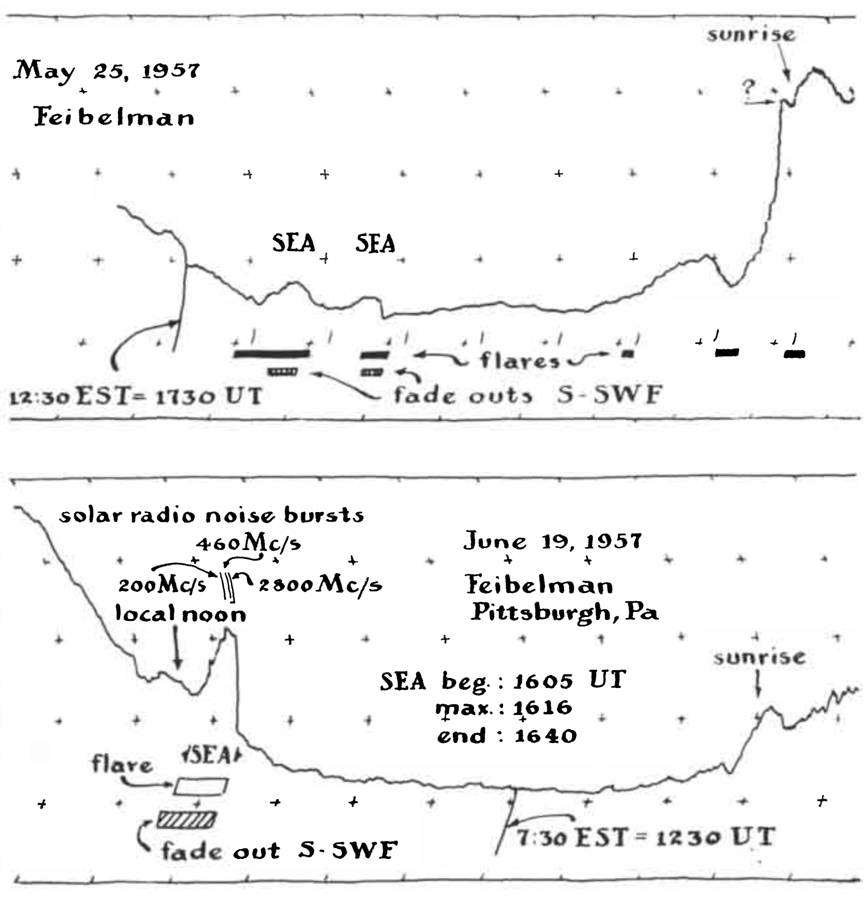
"In the meantime Walter A. Feibelman, a physicist of Pittsburgh, Pa., became interested in the project and built a station after Warshaw's design. In May, 1957, he submitted some of the clearest SEAs ever recorded by our patrol. Our second station was in operation. That fall another member, Val Isham of Powell, Ohio, assisted by G. H. Pieterson, put a station into operation. (He had made a previous attempt at Columbus, Ohio, but was frustrated by local noise.)

"The records submitted by these three stations compared favorably to those of professional observatories. Warshaw's design was vindicated. After examining these results Walter Orr Roberts, then chairman of the U. S.-IGY Solar Activity Panel, advised us that the Bureau of Standards would assign four Brown recorders to the project for a period of a year. Ellison, who had served as our consultant from the beginning, urged us to set up at least two stations in high latitudes. There, he thought, SEAs of greater amplitude would be detected.

"I do not know what difficulties professionals experience when establishing a network of observatories, but we had plenty. The matter of putting your finger on competent amateurs willing to stick with the job around the clock for a year is no easy chore. There is also the matter of equipment maintenance. Not all competent observers are good technicians. We could not afford to finance a roving trouble-shooter, although we soon had enough work to keep one busy. Some instruments were damaged in transit. Others failed in use. In addition, there was always the problem of tracking down sources of local noise and taking corrective action.

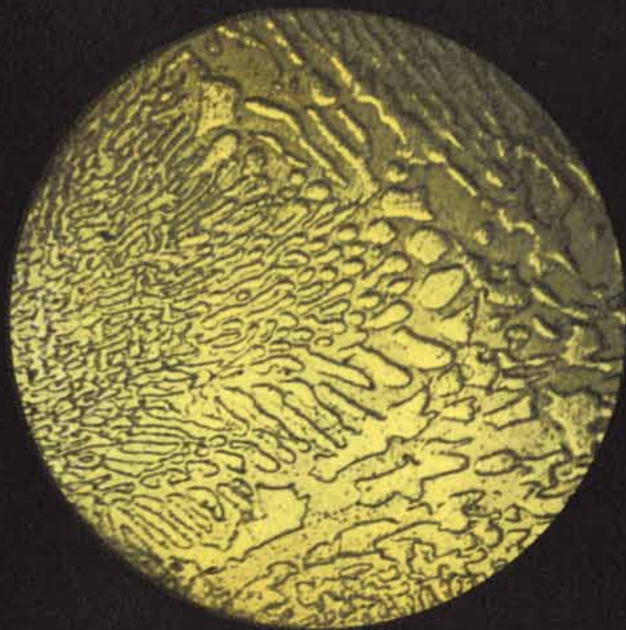
"The recruiting job was handled by correspondence, and after many exchanges we finally selected four locations for the recorders. It turned out that the chart drive of the Brown recorders ran too fast for our purpose. So we modified the instruments for a chart speed of one inch per hour. The recorders were then equipped with 27-kilocycle receivers built by Warshaw and were shipped.

"The new observers included Ralph Buckstaff of Oshkosh, Wis., who op-

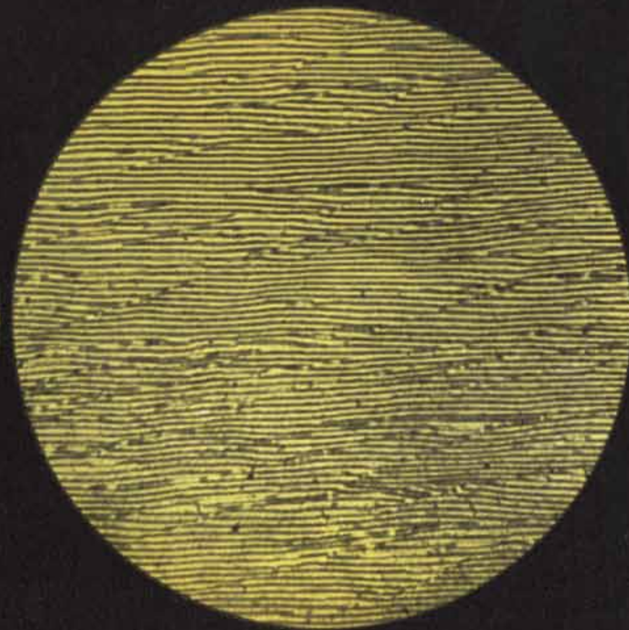


Typical recordings of sudden enhancements of atmospherics (SEAs)

Is a FUNDAMENTAL Research Program Worthwhile?



Normal binary eutectic structure (250X)



New binary eutectic structure (250X)

We, at the Research Laboratories, are convinced that it is worthwhile. For example, one of the fundamental scientific programs being undertaken is a study of the mechanism of solidification of polyphase alloys.

This study is still in its early stages. However, we now have a better understanding of the solidification process. And we have demonstrated that the microstructure of certain eutectics can be significantly altered by controlled solidification. The contrast is illustrated above.

It is possible that these binary alloys with preferred orientation may have unusual physical and mechanical properties.

Perhaps you are interested in corporate-sponsored studies into the fundamental nature of matter. If so, we can offer a research environment that seems to stimulate scientists to extra achievement. It may be due to the way we encourage an internal cross-fertilization of ideas; or because of a unique complex of complementary services that free the scientist from routine analysis and experimental chores.

Opportunities for scientists in the physics of solids, liquids, gases, and plasmas. Current studies range from the fundamental properties of matter to the application of scientific knowledge to promising new products.

• • •

For more specific information, please write to Mr. W. H. Walsh at the Research Laboratories.

RESEARCH LABORATORIES

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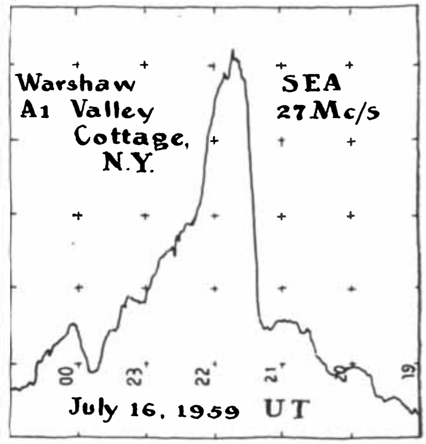
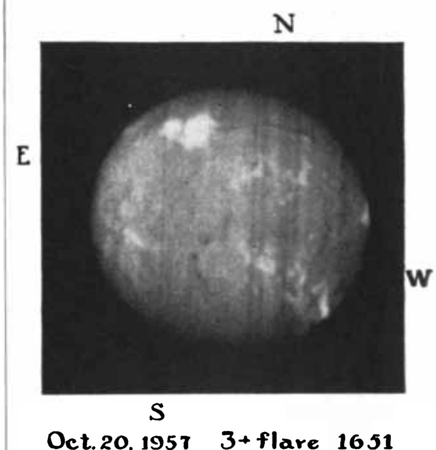


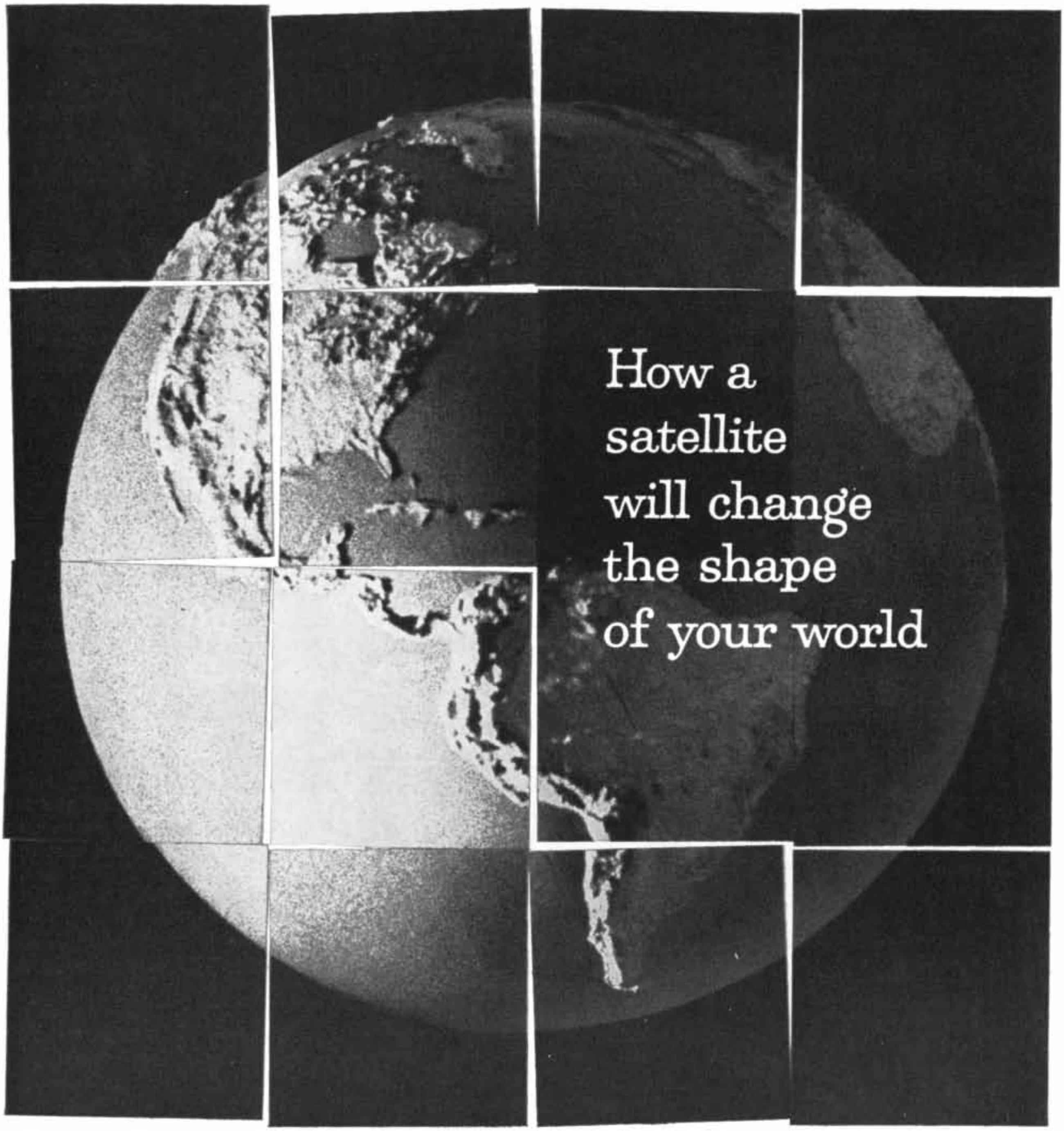


SEA recording (top) *and associated flare*

erates one of the world's most complete amateur astronomical observatories. Farther west we recruited Walter Scott Houston of Manhattan, Kan., another leading amateur astronomer. Our northernmost station was set up by Franklin Loehde in Edmonton, Alberta (54 degrees North). On the West Coast we had Robert Evans of Victoria, B.C.

"Despite the best efforts of all concerned, only one of the new stations contributed substantially to the flare-patrol program. In one case a trolley line created so much disturbance that the records could not be deciphered. This was the Edmonton station. A grave illness terminated the activity at Victoria. Limited success was achieved in Kansas, but power supplied by the rural electric line (for operating the recorder) proved to be so erratic that systematic records could not be kept. The station maintained by Buckstaff was productive.

"While these installations were on trial C. H. Hossfield of Ramsey, N.J., assembled an apparatus of his own. Although situated well within the metropolitan area of New York City, this station has made the clearest records sub-



The "Doubting Thomas" who questions the practical value of today's space shots is answered by a growing list of useful satellites...

Just as a military need for radar helped you have TV sooner, so you can expect peacetime benefits to come from rocket and missile research.

Space probes have already revised our concept of Mother Earth's figure. Now geographers suggest maps made by camera from a cartographic satellite. It would give us the first completely accurate map of the world—a project of major value in defense.

While the map-making satellite is still to come, a rocket that can orbit it—the Douglas *Thor*—is already called "workhorse of the Space Age." It has been successful in more than 86% of its space firings. It boosted the first nose cone recovered at ICBM range, and is already deployed at NATO sites abroad. Now the Douglas *Delta*, NASA's advanced research version of *Thor*, is ready to probe even deeper into space.

A series of satellites which will add to our knowledge of the world we live in are going into orbit. The key space vehicle in this major NASA research project is *Delta*, for which Douglas is system manager and producer.

DOUGLAS

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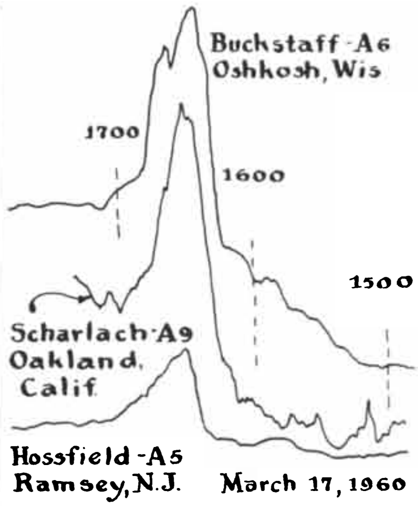
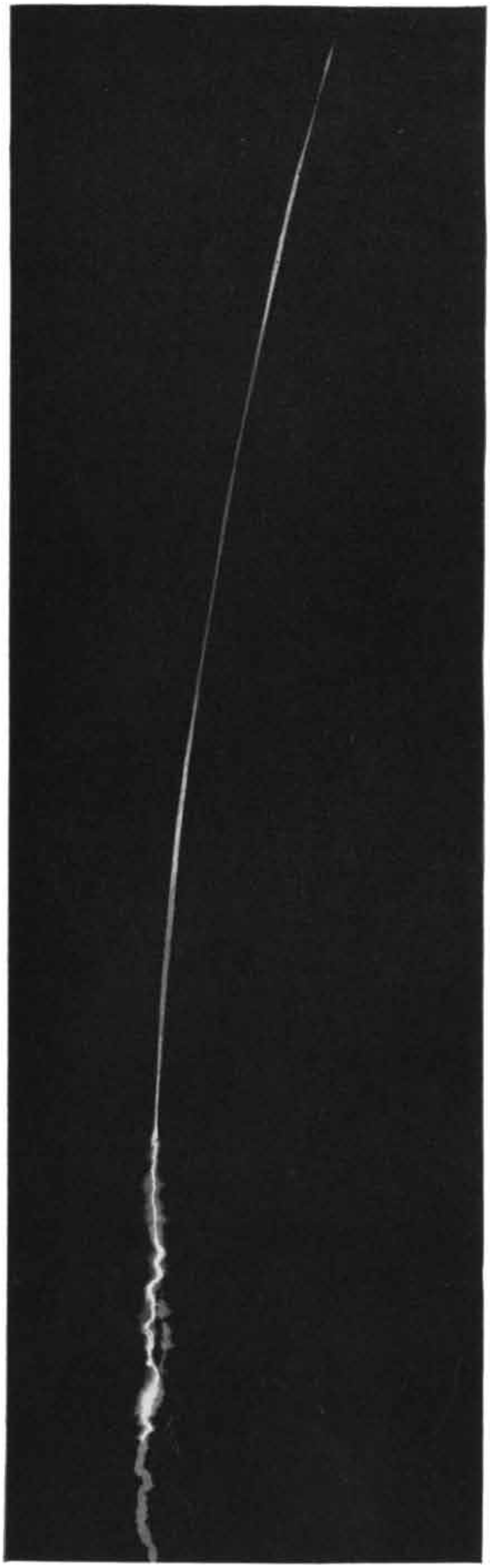


A SEA recorded at three locations

mitted by our patrol. For some reason Ramsey is relatively free of man-made electrical disturbances.

"By the end of 1957 Justin Ruhge, a physicist of China Lake, Calif., had built a Warshaw flare-recorder and set it up for automatic operation in an isolated desert shack. His station, the southernmost in our group, records SEAs of the highest amplitude as well as those with the greatest change in signal level between night and day. Recently Stanislaus Scharlach, a Dominican priest who is a student of physics and spectroscopy in Oakland, Calif., completed a station and joined the patrol. Other late recruits include Harvey Hepworth of Blauvelt, N.Y., Hans Arber of Manila in the Philippines and Pierre R. Gouin, director of the geophysical observatory of University College at Addis Ababa in Ethiopia. All these observers send their records to me, and after analysis I forward the results to the Bureau of Standards and the AAVSO.

"What do SEA recordings show? Typically a 24-hour graph displays high-amplitude signals during the night, followed by a low-level trace beginning at sunrise. This characteristic is explained by the formation of the D layer at sunrise. The long waves emitted by ever present thunderstorms in the tropics reach the higher ionospheric layers by an unimpeded path at night and are reflected to the surface without significant loss of energy. During the day, however, the waves must traverse the lower and lightly ionized D layer. Because of its light ionization, the D layer acts not as a reflector of electromagnetic energy at long wavelengths but as a partial absorber. This loss of energy to the D layer accounts for the precipitous dip in the re-



Conquest of the Thought Barrier

Over the years, we have been hearing of many "barriers" in science . . . the sound barrier, the water barrier, the thermal barrier.

Of all the barriers, the hardest one to break through has always been the thought barrier. Every one of these "barriers" has been conquered by men to whom the word, impossible, means only: "hasn't been done, *yet*."

The sound barrier is a shattered concept, as discredited as the phlogistic theory.

Don Campbell's *Bluebird* stopped all talk of the water barrier.

The heat of air friction against the metal "skin" of an airplane was supposed to create a heat barrier at Mach 3. Materials now in production can safely withstand the much higher temperatures involved in flight at Mach 5.

Today the thermal barrier is being called the "thermal thicket"—evidence in itself that no barrier exists.

An interesting point that all of these "barriers" have in common: each was conquered with the help of nickel-containing alloys.

This is not surprising when you stop to consider how many useful properties and combinations of properties are offered by the various nickel alloys:

Corrosion resistance to a wide variety of solids, liquids and gases . . . strength at high temperatures . . . toughness at sub-zero temperatures . . . unusual electrical properties . . . ability to protect product purity . . . spring properties . . .

When you are faced with a metal problem, investigate Nickel and its alloys. There is a good chance some nickel-containing alloy will help you break through what others consider a thought barrier.

INCO TRADE MARK THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER cordings with the approach of sunrise. SEAs appear on the graphs during the hours of daylight, because X-rays and ultraviolet rays emitted by solar flares impinge on the D layer and increase the intensity of its ionization. The D layer then functions as a reflector, and the amplitude of recorded signals increases as shown in the accompanying graphs [*page 234*].

"An exceptionally clear SEA is depicted in the graph made by Warshaw on July 16, 1959 [*page 236*]. Note the sharp rise at the right side of the graph, marking the onset of the flare, and the characteristic jagged decline at the left side. This SEA was caused by the large flare shown in the accompanying spectroheliogram, made by Ben Parmenter of Spokane, Wash. Most SEA recordings take this general shape, but the magnitude and detail recorded vary with the location of the station. This is illustrated by the graphs of a flare recorded simultaneously on March 17, 1960, at Oshkosh, Wis., Oakland, Calif., and Ramsey, N.J. [*page 238*].

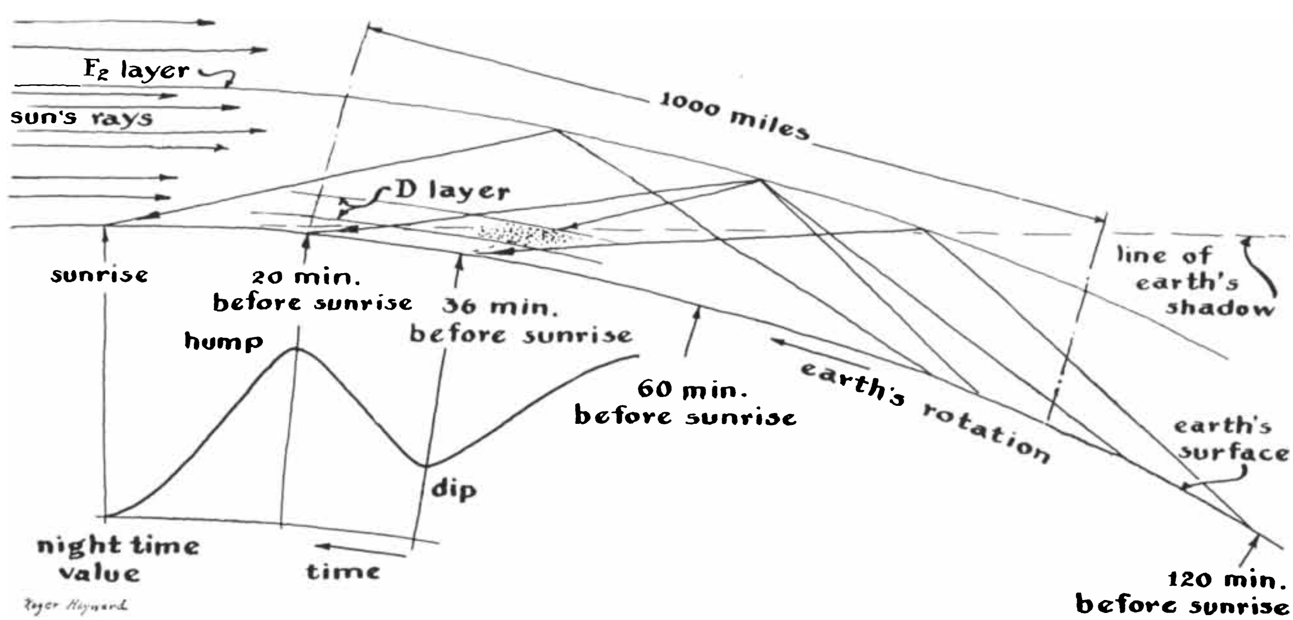
"Proficiency in distinguishing SEAs from other disturbances comes with practice. The observer will acquire the knack by the time he has analyzed his first half-mile of graph paper. Then the recordings can become exciting. When you spot a big flare, you can confidently predict a black-out in short-wave radio communications within 26 hours, the interval required for the cloud of electrically charged particles ejected by the flare to reach the earth from the sun. Their arrival is often signaled by auroral displays in high latitudes, the onset of magnetic storms and the more or less severe disruption of electrical communications. Unfortunately there appears to be no direct relationship between the size of a flare and the amplitude of the resulting SEA. Large flares are often accompanied by small SEAs, and the opposite is also true.

"By the spring of 1957 our stations were functioning routinely. As I have mentioned, my task was to find some meaningful regularity in the seemingly random traces. One gross pattern, immediately evident in 80 per cent of the records, was the diurnal variation in signal intensity. The graph dips at sunrise, and rises with the approach of sunset.

"A close examination of the sunrise traces disclosed an interesting and equally regular pattern first observed in one fortuitous sequence of recordings that spanned 14 days. These disclosed that the signal level does not drop abruptly with the approach of dawn. Instead, the amplitude wavers for about 90 minutes, during which time four characteristic elements are observed. Some 45 minutes before the local sunrise the curve has a pronounced dip. About 10 minutes later a typical hump appears. I have termed this the precursor hump. The hump gradually slopes off with the approach of sunrise. The signal intensity then falls to its daytime level. Finally, about 50 minutes after sunrise, occasional recordings show a 'post-sunrise hump' of varying duration and intensity. To the best of our knowledge this detailed sunrise pattern had not been recognized prior to the analysis of our data.

"What are the implications of the pattern? Although the question is still open, Warshaw has suggested one interesting explanation. The phenomenon could be accounted for by a detached zone of low ionization that forms at an altitude of about 50 miles on the dark side of the sunrise terminator (the line between the illuminated and dark side of the earth). This zone might be described as a detached portion of the D layer. Signals reflected from a higher layer would be partially absorbed by the detached zone during their downward transit, an effect that would account for the predawn dip. Then, some 20 minutes before sunrise, the earth's rotation would advance the detached zone three or four degrees and would again establish a clear path for the reflections. The precursor hump would now appear, as the signal intensity approached its nighttime value. Warshaw suggests that the atmosphere in the detached zone may be ionized to about the normal intensity of the D layer by ultraviolet rays that proceed through the atmosphere on the lighted side of the terminator and impinge on the detached zone at the optimum angle for creating ionization. The accompanying chart [*below*] depicts the suggested mechanism together with an idealized graph of the sunrise pattern.

"No explanation has been advanced for the occasional post-sunrise hump. Its existence has been clearly established, however. Ellison has observed it on a number of occasions. On this side of the Atlantic the effect appears most clearly in the records of our station in China Lake, Calif. If you should decide to undertake the interpretation of flare record-



A diagram suggesting the mechanism of the "precursor hump"

THIS IS GLASS

A BULLETIN OF PRACTICAL NEW IDEAS FROM CORNING

NO PLACE FOR AN ACROPHOBE

When first we read of the seven who are eager to blaze a route to the stars, we pondered what we thought of as man's inborn fear of great heights.

Now we learn that the first of the astronauts will have a window in his capsule, that he will peer *down* at the spinning earth and *out* at the wheeling stars.

We are producing these unique, space-going viewports for McDonnell Aircraft Corporation, prime contractor for the National Aeronautics and Space Administration's Project Mercury capsule.

The window is an excellent piece of engineering. Not just because we made it, but because it *has* to be.

It will take the slams and whams, the blistering heat, and the embrittling cold of blast-off, orbitation, re-entry, and a soak in the briny. All during this it must remain transparent, intact, and sealed tight.

There are four panes to the window. The outer two are VYCOR® 96% silica glass. The inner two are aluminosilicate glass specially tempered to phenomenal strength.

Each pane is ground and polished to the precision finish of a telescope mirror. The outermost panel curves to the contour of the capsule, so it trapezoids from an 11″ base to a 7½″ top along a 21″ height.

The glasses present a delicate balance of optical qualities, thermal shock resistance, and low weight. The last is vital when you consider that it takes about 100 gm of fuel to orbit 1 gm of payload.

So, remember, when you see the first astronaut smiling quietly, confidently from his capsule, you are looking at him through Corning glass.

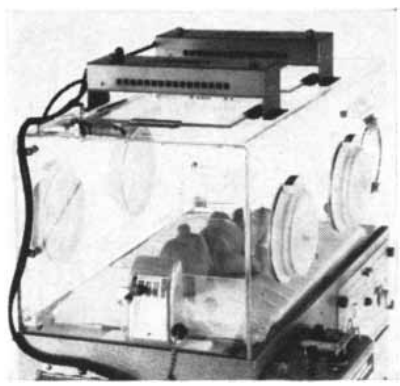
HOW ABOUT A DEGREE IN MEDICAL ENGINEERING?

The mechanics of modern medicine are fast maturing to the point where some engineers are specializing in the building of machines like this Infant Servo-Controller for the Isolette, manufactured by Air-Shields, Inc., Hatboro, Pennsylvania.

This particular machine is used with prematurely born infants who must keep their body temperature at a constant level, but lack a well-developed thermal regulatory device.

You attach a thermistor to the babe's abdomen and let him work as his own thermostat. He automatically requests heat from infrared lamps whenever his skin temperature drops below 97°F. When things are just right again, he switches off the lamps and takes a rest, with the odds for survival more in his favor.

If you've ever tried to unbulb an infrared lamp, you know that it gives off *direct* heat as well as IR energy.

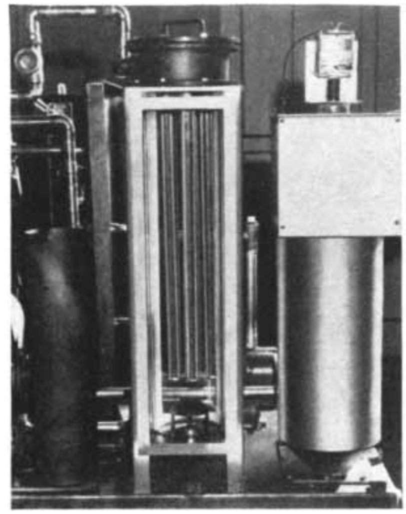


That's why there are two PYREX No. 7740 glass plates sitting on top of the plastic chamber in the picture. You can see them, if you look closely. The PYREX plates are heat resistant and will also dissipate the *direct* thermal output of the lamps. So, the plastic forgets the lamps are there.

As far as the IR energy is concerned, the PYREX plates don't exist either, so practically all the IR gets through to the baby.

The over-all relationship between IR and glass is an odd one. We can give you glass which transmits as much as 92% of the IR or a glass which transmits as little as 8% of the IR.

Happily for our product specialists, there is demand for both situations. We've prepared some bulletins on many of these IR characteristics, a copy of which you may have by sending the coupon.



SOMETIMES GLASS IS SO OBVIOUS

Leafing our way through the 4th Annual Shirt Issue of "Cleaning Laundry World" (April 1960), we took note of an advertisement which concerned a machine which displayed a feature which we consider the soul of genius.

The machine is a dry cleaner manufactured by Detrex Chemical Industries, Inc. The feature is a glass-enclosed filter which keeps the dry-cleaning solvent cycling unpolluted. The soul of genius, to our minds, consists of intelligent manipulation of the obvious . . . in this case, an application of the first known and longest respected of the myriad properties of glass . . . to wit, its *transparency.*

When you locate such a place, it doesn't necessarily take a lot of redesigning of custom fabrication to put glass to work, either. We checked and found that Detrex, for example, simply orders standard 6″ O.D. PYREX brand Heavy Duty Tube for its filter wall.

The result is that the operator of the Detrex Cleaner can watch the filter at work. He can spot trouble while it's still potential, determine its cause exactly should it occur . . . all without any dismantling or shutdown.

Is there anything you're working on that you wish you could watch working? If there is, and you want to put glass to work, you can start by sending the coupon for a copy of Bulletin IZ-1, "Designing with Glass for Industrial, Commercial, and Consumer Applications."

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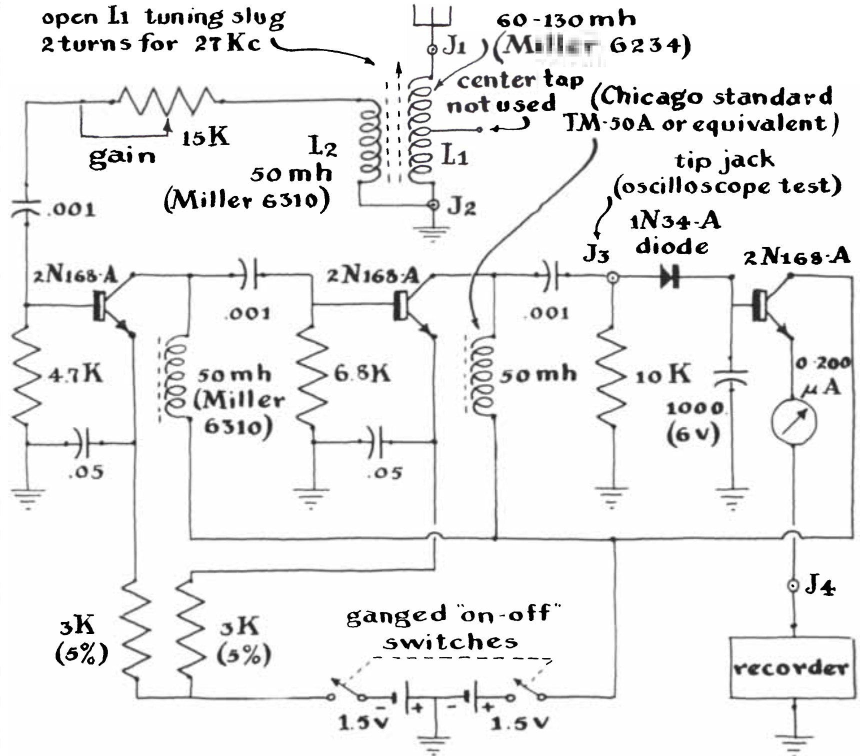


Circuit diagram of the SEA receiver

ings, you will discover that the post-sunrise hump can be vexing in the extreme. It resembles nothing so much as a clear SEA recording.

"Usually the graph begins a gradual climb in the afternoon. (The band becomes noisier.) This is to be expected, because the number of local thunderstorms, in addition to those in the tropics, increases during the latter half of the day. The signal pattern thus reveals its meteorological origin. Our records show that relatively quiet a.m. periods exceed quiet p.m. periods by a ratio of 10 to one. In spite of this there is a strange excess of SEAs during the p.m. hours. Roughly 1.6 times as many SEAs—about 62 per cent of the total—are recorded in the afternoon.

"Nighttime fluctuations are particularly great; frequently pseudo-SEAs appear. We even have some examples of pseudo-SEAs recorded at night that coincide with the onset of flares. As Ellison has pointed out, however, one cannot properly classify such patterns as SEAs.

"We have adopted the classification system for reporting SEA data which was proposed by J. Virginia Lincoln, Chief of the Radio Warning Services Section of the Bureau of Standards, and which was described in Bureau of Standards Report 5540 (November, 1957). According to this system, the amplitude of SEAs ranges from 1— (lowest in amplitude) to 3+ (highest). Further, we rate the certainty with which the identity of a SEA is established. This scale ranges from 5 (definite) to 0 (questionable). We have recorded approximately 2,000 SEAs to date. Of these, five of our stations submitted 1,060, almost 13 SEAs per month per station.

"What good are our recordings? For one thing, they correlate satisfactorily with those made by the official observatories. We catch some SEAs that are missed by the official stations, and vice versa. In a letter extending the loan of the Bureau of Standards recorders Walter Orr Roberts has written: 'Miss Lincoln is very pleased with the data she has been receiving from your people and we feel that this program is making an important contribution to the observing effort.'

"If you decide to go in for flare recording you should not find Warshaw's receiver particularly difficult to duplicate. The parts are available from most dealers in radio supplies and are interconnected as shown by the accompanying circuit diagram [*above*]. All resistors are of 1/2-watt capacity and should be within 10 per cent of the value specified, except as has been indicated in the diagram.

"Warshaw suggests the use of No. 14 solid-copper plastic-covered wire for the ground bus, an arrangement that a report on:

WHY ENGINEERS & SCIENTISTS CHOOSE HMED FOR CAREERS IN ELECTRONICS

Independent Survey* reveals motivations and goals that lead professional men to join General Electric's HEAVY MILITARY ELECTRONICS DEPARTMENT.

From time to time a company likes to compare its image of itself with the image seen by engineers and scientists who visit its facilities. One of the best ways to do this is to go to engineers and scientists who have had this experience, give them a cloak of anonymity, and invite them to sound off.

We did just this recently at HMED. At our request, a group of technical manpower consultants devised a comprehensive questionnaire which was presented to 131** EE's, physicists, mathematicians, and industrial and mechanical engineers who joined the Department in the past year. And we're pleased enough with the results to want to pass them on.

The graph below summarizes the key points that induced these men to join HMED, based on their own appraisal of the company at plant interviews. Notice that the depth, interest and variety of HMED's electronics programs are the factors that led all others. Also a major influence was our tuition refund graduate study program at nearby Syracuse University, and our extensive program of in-plant technical courses.

This interest in advanced education didn't surprise us—it's been typical of HMED *men through the years. In the Spring of 1960, 73 engineers and scientists were working toward advanced degrees at Syracuse University. 610 were enrolled in in-plant courses ranging from Electromagnetic Field to Automatic Control Systems, and 11 studied technical Russian.*

Going beyond the basic questionnaire, engineers and scientists were given an opportunity to express themselves at length on varied subjects. Concerning HMED's "working conditions" (5th motivating factor on the graph), respondents praised these aspects of our creative environment: "*...the diversity of high-level engineering and research being done in such a pleasant atmosphere;*" "*...the company's policies and interest in the individual;*" "*...treatment as a professional person;*" "*...atmosphere of cooperation and pride of achievement;*" "*...association with leading men in my field.*"

We feel this survey corroborates our belief that the special character and technical objectives of HMED are communicated clearly to professional persons visiting the plant. To us, the results indicate that engineers and scientists of various ages, experience and disciplines appreciate our particular regard for the professional man...our efforts to give him problems worthy of his talents...our support of his career fulfillment. We think these beliefs are borne out by our low engineering turnover, which has been less than 4% over the 5-year period of 1955 to 1959.

If you are an engineer or scientist who would like to learn more about HMED, please write of your interests and experience to Mr. George B. Callender. He will arrange a convenient, pre-paid interview for those qualified for senior positions in these areas: RADAR / SONAR / COMMUNICATIONS / DATA PROCESSING & DISPLAY / MISSILE GUIDANCE & CONTROL / ELECTRONIC CONTROLS.

HEAVY MILITARY ELECTRONICS DEPARTMENT

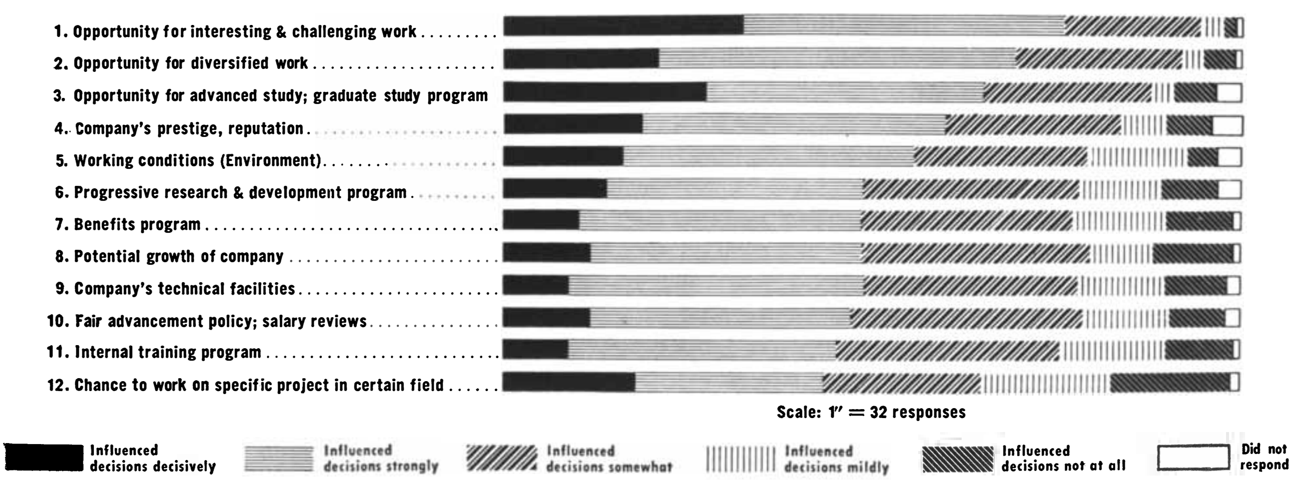
GENERAL ELECTRIC

Dept. 59-MI, Court Street, Syracuse, New York

*Devised and analyzed by Employee Communications. Inc.,N.Y.C.

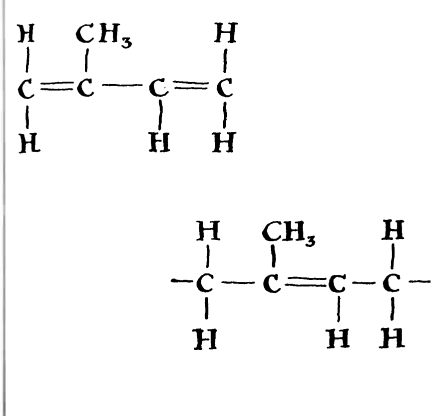
** This group ranges from age 21 to over 45. Three-quarters are between 21 and 35, with 40% in the 26-30 age group. 86% are married. 115 hold bachelors degrees; 8 have masters.

Motivational Appeals Having Strong or Decisive Influence in the Decision of Professional Men to Accept Positions with HMED.

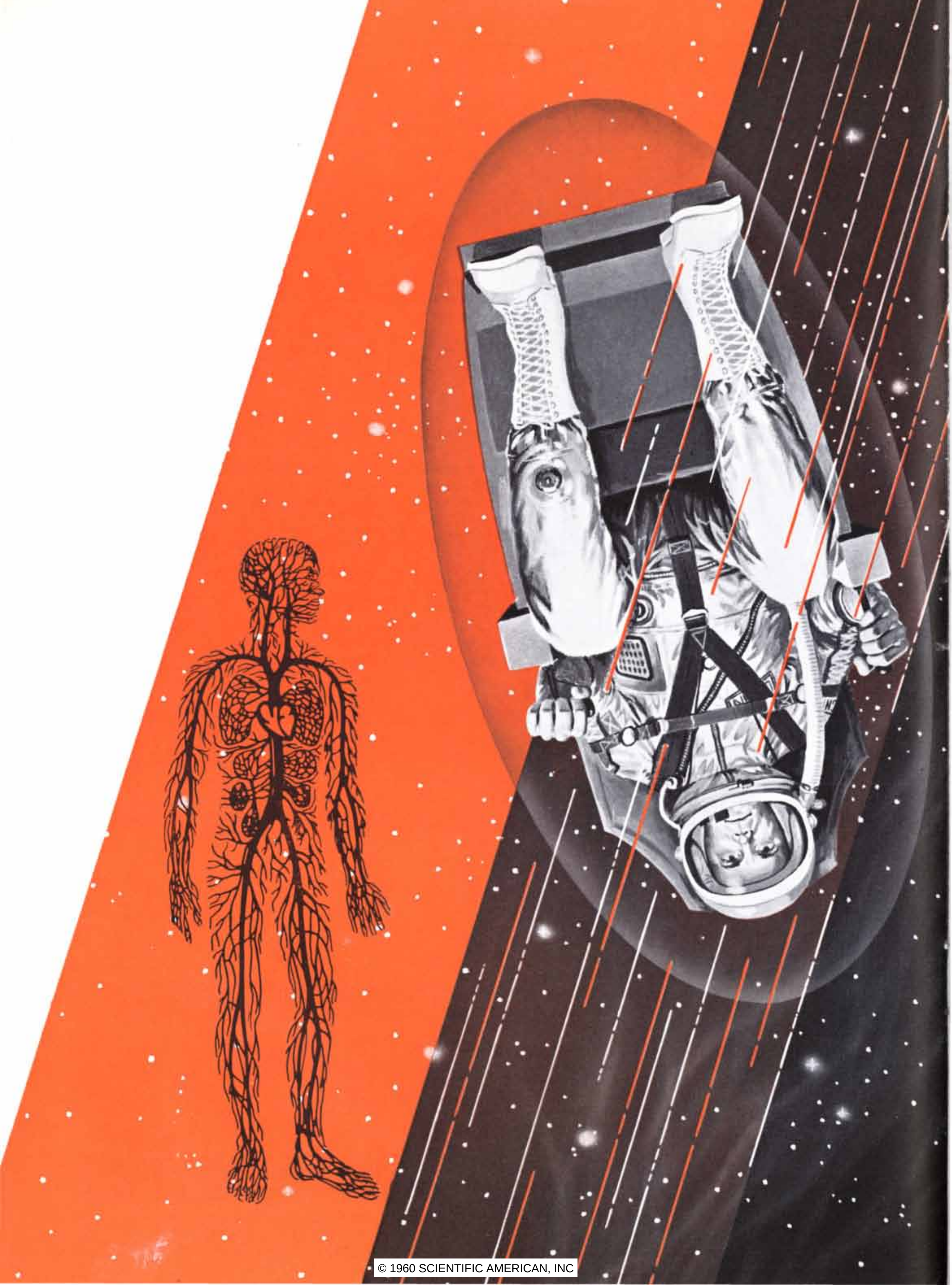


provides a solid mechanical support for the coils. The coils designated L_1 and L_2 must be mounted side by side and spaced approximately half an inch apart. The remaining coils are mounted at right angles to L_1 and L_2 and perpendicular to each other. In other words, if L_1 and L_2 are mounted vertically, one of the two remaining coils must be mounted east and west, and the other north and south. This arrangement minimizes magnetic coupling in the coil assembly and prevents the receiver from going into uncontrolled oscillation. The coils contain ferromagnetic slugs, and the slug of L_1 is adjustable for tuning the receiver. For operation at 27 kilocycles the screw supporting the L_1 slug is first run home and then backed out two full turns. When wiring the receiver, it should be recalled that transistors are easily damaged by heat. Do not solder transistor leads. Cut them to a length of about half an inch, and make the circuit connection either by means of binding posts or by spring clamps salvaged from a miniature vacuum-tube socket. The current drain on each flashlight cell approximates only 500 microamperes, hence the batteries should last their normal shelf-life. The output of the receiver is sufficient to drive a 200-microampere pen movement to full scale when signals of maximum amplitude impinge on an L-type antenna 100 feet or more in length."

Several readers have called our attention to two errors in the article on amateur experiments with rubber that appeared in this department in June. Hevea latex is a dispersion of polyisoprene in water, not monomeric isoprene as stated. Moreover, the double-bond structure of the isoprene unit and isoprene molecule were reversed in the illustration. The correct structural formulas are given below.



Isoprene molecule (top) *and isoprene unit*



Pilâtre de Rozier and Marquis d'Arlandes (November 21, 1783), using a Montgolfier balloon, were the first to leave the earth to test man's physiologic reactions. This experiment was the forerunner of intensive Space Medicine studies of today.

SPACE MEDICINE

There is a relatively narrow zone above the surface of the earth in which man's physiologic mechanism can function. Hence the unrelenting search by Lockheed scientists into many aspects of Space Medicine.

Engineers already have equipped man with the vehicle for space travel. Medical researchers now are investigating many factors incident to the maintenance of space life—to make possible man's flight into the depths of space. Placing man in a wholly new environment requires knowledge far beyond our current grasp of human biology. Here are some of the problems under investigation: The determination of man's reactions; the necessity of operating in a completely closed system compatible with man's physiological requirements (oxygen and carbon dioxide content, food, barometric pressure, humidity and temperature control); explosive decompression; psycho-physiological difficulties of spatial disorientation as a result of weightlessness; toxicology of metabolites and propellants; effects of cosmic, solar and nuclear ionizing radiation and protective shielding and treatment; effects on man's circulatory system from accelerative and decelerative G forces; the establishment of a thermoneutral range for man to exist through preflight, flight and reentry; regeneration of water and food.

Exploration into unknown areas such as Space Medicine, provides endless stimulation to imaginative scientists and creative engineers. Research at Lockheed's Missiles and Space Division covers the entire spectrum—from pure basic research to development work, in support of current projects. Space Medicine is but one phase of Lockheed's complete systems capability in missiles and satellites. To maintain this position of leadership calls for an extensive research and development program—ranging from electrical propulsion research to advanced computer research, design and development. Typical current projects are: Man in space; oceanography; fuel cells; space station; space navigation; solid state electronics.

Engineers and Scientists: If you are experienced in work related to any of the above areas, you are invited to write: Research and Development Staff, Dept. I-36, 962 W. El Camino Real, Sunnyvale, California. U.S. citizenship or existing Department of Defense industrial security clearance required.

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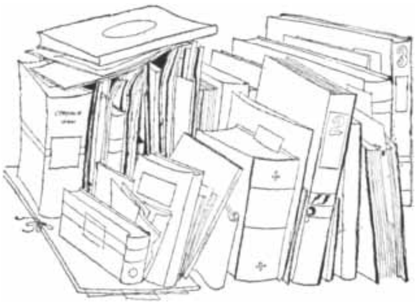

BOOKS

About the role of scientific inquiry in the Western intellectual tradition

by C. P. Snow

THE WESTERN INTELLECTUAL TRADITION: FROM LEONARDO TO HEGEL, by J. Bronowski and Bruce Mazlish. Harper & Brothers ($7.50).

This is a valuable and brilliant book. Bronowski is well known in England as one of the best expositors we have. I have never heard anyone better at explaining scientific ideas to a nonscientific audience, and except for W. L. Bragg it is hard to name an equal. In Mazlish, Bronowski has found a collaborator whose approach and mental clarity are obviously similar to his own. The result is a book that I should like to see on reading lists in colleges all over the U. S.

At this point I think I should "declare my interest," as they say in English committees. I can't pretend to be detached about a book like this. It is the kind of book I have been calling for, on both suitable and unsuitable occasions, for a long time past. Now that it has arrived I am not going to look a gift horse in the mouth. In my opinion Bronowski and Mazlish have done a real public service. Let's celebrate it by spreading the book as widely as we can.

They have set about tracing what I think could be called the *line of reason* from the high Renaissance to Hegel (a rather odd point to stop, but there are faint indications that they are going to produce a second volume, bringing the story down to the present day). This is an intellectual history, and is deliberately intended to be so, with eyes open to the rarefactions, the removal from the dust and sweat of lives as they have actually been lived, which that implies. Both authors seem to be tolerant, sunny-minded, basically optimistic men: and the hero of their book, who is emerging pretty victorious by the end, is the spirit of scientific inquiry. They see the recognition of scientific thought, and its seeping into all the fields of mental life, as the characteristic feature of their period. To them, *that* is the Western intellectual tradition.

I think they are broadly right. If anyone else quarrels with them, I am on their side. But it may be worth while to throw in a few doubts, carpings and qualifications, from someone who is an admiring ally, but who is generally more suspicious, and certainly more suspicious of ideas, than they are.

So let me be an *advocatus diaboli* for a bit. Western intellectual tradition? Why Western? Surely Joseph Needham has demonstrated that there was no difference in kind between scientific thinking in the Western Renaissance and in China under the Mings. The interesting point is why the great blowup of the scientific revolution didn't also take place in China. What were the social correlatives of this scientific thinking which in the West produced a revolution and in China kept the society rigid? This is the kind of question which Bronowski and Mazlish are sometimes prepared to raise, even though it is all mixed up in the plasma of society, while by preference they like intellectual problems a good deal purer. But one of their strengths is that about Western history they don't shirk these questions: that is a point to which I shall return.

As for the Western part of their title, it is rather important—if we are not going to fall into the traps of Western technological conceit, which have gone some distance toward losing the West the world—to realize that there is nothing specifically Western about the curious process of what Bronowski and Mazlish call "rational inquiry and empirical experiment," which is nothing more or less than science itself. It is a curious process. It is more complex and less sharp-edged than the phrase above suggests. Yet it is a process which, in the right social conditions, almost all human minds, Eastern quite as much as Western, find both easy to handle and alluringly attractive.

In the U. S. or the U. S. S. R. or China or Western Europe today, children are born into what used to be described grandiloquently as the scientific method. It is not something that needs teaching. Ernest Rutherford, in his more Johnsonian moods, used to say: "We shall get on all right if *those fellows* leave us alone." "Those fellows" were the methodologists and philosophers of science, who in Rutherford's view merely cluttered up the easy and natural practice of discovery: they made the commonplace incomprehensible. Rutherford took his bluffest tone toward their activities. "All hot air! All hot air!", he trumpeted. Nothing really mattered, in his view, but the "real stuff," the knots of creative work floating in the sea of talk, the original papers, the paintings, the histories, novels and plays. (He warmly approved of those.)

Well, that is an extreme view and not one I should be prepared to defend. But it is a view that we ought to keep in reserve, so to speak, when we pass from the word "Western" to the word "tradition." Tradition is a dangerous term. It often means that out of the welter and brute muddle of the past one has selected just those elements which prove one's case. The classical recent example of Cutting Tradition to Fit One's Cloth is that of F. R. Leavis, one of the "new critics," on the English novel. By eliminating Dickens and the rest, he proves to his own satisfaction that the great tradition of the English novel is Jane Austen—George Eliot—Henry James—Conrad—D. H. Lawrence. There is nothing so blinkered about the way in which Bronowski and Mazlish have set about selecting their tradition, but it is in part eccentric. They have wisely set out to deal with some intellects in detail, but the names of those intellects are sometimes not those which a man like Rutherford would have chosen. Leonardo—Machiavelli—Thomas More—Erasmus—Luther—Calvin—Copernicus—Galileo—Raleigh—Sidney—Cromwell—Huygens—Hooke—Newton—Hobbes—Locke—Descartes—Pascal—Beyle—Voltaire—Montesquieu—Rousseau—Joseph Priestley—Adam Smith—Benjamin Franklin—Jefferson—Burke—Bentham—Robert Owen—Kant—Hegel. That, with some minor additions and some discussions of groups such as the Jacobins, represents the series: and it is, at the first glance, an unusual one. Part of the value of the book is, of course, that the series *is* an unusual one. No book of this kind has ever dealt with such mastery, not only with individual performances by scientists, but also with their effect on the world's intellectual stream. The chapters in the book on Leonardo, Newton and Descartes are especially brilliant.

But some members of the series ring more than a little odd. They give the effect of a conglomeration, rather than a synthesis, of science (in particular physical science), textbook philosophy and certain kinds of history. The authors' bias is in favor of the easily explicable, and against the tangled and not easily docketed. It is significant that no writer of heavy weight and no complex work of literary art gets any sort of serious treatment. Yet during this period Shakespeare, Cervantes, Milton, Racine, Goethe, were all doing their modest best. It is also significant that the darker spokesmen (or exemplars) of man's fate do not get a hearing. Dr. Johnson, for example, is a voice speaking for the irremediable in human life—a far deeper and in many ways more influential voice than either Hobbes or Burke. These omissions give a certain streamlined effect to the Bronowski-Mazlish tradition which another kind of selection from the West's intellectual material would not be able to possess.

The general result is to make life, including intellectual life, somewhat more bland than it really is. This blandness of tone will put some readers' backs up. There are times when one gets a bit tired of Uncle Bronowski and Uncle Mazlish smoothing down all the snags, and one feels like saying something like what Hazlitt said of Shelley: "He is clogged by no dull system of realities, no earth-bound feelings, no rooted prejudices, by nothing that belongs to the mighty trunk and hard husk of nature and habit."

That, however, is my last grumble. They have three great strengths, any one of which would have justified this book and made most of us proud to write it. The first is, they have established, to their own satisfaction and the satisfaction of everyone who reads their argument (unless he is a perverse reactionary of the type of T. E. Hulme) that in essence all intellectual developments from 1450 to 1850 take their nature from science. Whether they are scientific or not, they are inspired by the scientific process. Once men got the knack of reason-plus-experiment, or whatever we like to call it, there was no kind of thinking, no kind of art, even no kind of politics, which could remain immune for long.

This process one can see beginning in the great Renaissance painters, whom Bronowski and Mazlish personify in Leonardo. They could equally well have chosen Verrocchio or Mantegna or Piero della Francesca, all of whom were mathematicians, all of whom tried to find, through their art, mathematical and scientific laws. (Just as Proust in our century set himself through his great novel the essentially scientific task of discovering *les grands lois.*) There was just the same assumption of the scientific component in art present in the writers of the Enlightenment. Voltaire wouldn't have thought there was any fundamental distinction in aim between his (very unsuccessful) experiments in physics and his (rather more successful) *Candide.* Even as late as the Romantic poets or the classical 19th-century novelists who came just after the close of Bronowski's and Mazlish's period, there was still some feeling of kinship of intention, some sympathy of the writers for the scientific triumph.

Of course none of them realized the depth and extent of that triumph. It is only with the hindsight of history that Bronowski and Mazlish can show us Bentham, Jefferson, Kant and Hegel as part of a process that began with Copernicus and Kepler. But still, by the early 19th century a good many nonscientists could hear the clumping footsteps of science behind them. Shelley, for instance, heard them very clearly. Curiously enough, he liked the noise and knew more about science than any of the other Romantics. Even Wordsworth wrote a singularly uninspired verse in celebration of geometry.

During these 400 years while scientific thought was making its way, there weren't yet two cultures in the sense that I have recently been trying to define. That split came later; and it came, perversely, because of the blinding success of science. The success was blinding in two distinct ways. The first was the practical success of the scientific-industrial revolution. When this started, there was some excuse for people of sensitivity not to recognize what it meant. One had to be pretty thoroughly oriented toward the future in early 19th-century England or America to see the good to come. A tough-fibered man like Macaulay could see it, which is one of the reasons why reactionary intellectuals hate him. He had the foresight and the unfinicky humanity to know that this revolution was going to transform, and transform benef-

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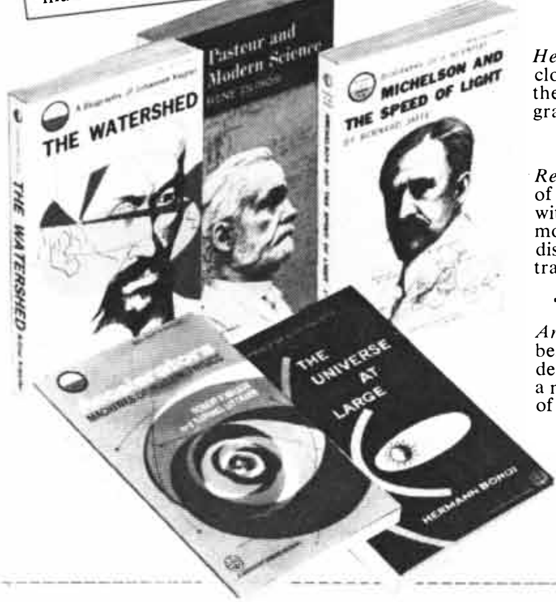

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icently, the lives of the poor. But he was a historian, with a mind stretching into the past and into the future. Most literary people by temperament live in the existential moment; and the existential moment in the first stage of the industrial revolution was usually not pretty.

One finds Wordsworth brooding, not inhumanly, over the problem in *The Excursion.* Almost no other major Western writer afterward had even that degree of historical imagination. Their eyes kept turning back, as they have turned even more passionately in our own time, to a pre-industrial (and fictitious) past.

The second aspect of the success of science which caused the cultures to split was simply that scientific thought had been *too* successful. Bronowski and Mazlish have shown, with piercing thoroughness, how widely it was pervading all the domains of intellectual life. It is understandable enough that this science produced a kind of antiscience, felt most deeply, of course, by those who had themselves no taste for scientific thinking and who accordingly (and this was often the fault of the scientists themselves) misunderstood its nature. By about the middle of the 19th century there were men of great gifts who attributed to scientific thought claims which it could not properly make and which to them appeared to threaten the numinous wonder of the world.

The first passionate statements of this antiscience can be heard in existential philosophies like Kierkegaard's. By the end of the century they were becoming fairly common in literary art. Between 1900 and 1914 antiscience was becoming part of the fiber of a whole new artistic approach (Ezra Pound, Wyndham Lewis and W. B. Yeats are spectacular examples).

So the intellectual tradition which Bronowski and Mazlish demonstrate had at last broken. Probably it will not appear, in the perspective of history, as an important break. Their tradition has continued and has had greater triumphs; it is overwhelmingly the major and prevailing tradition of the entire modern world. Nevertheless, we ought not to pretend that there has not been, among many persons of artistic sensibility, a reactionary contracting-out. As scientific thought has made its major conquests, exponents of 20th-century art, including some of the most gifted, have plunged into a mélange of anti-intellectualism and primitivism. The type-specimen of this reaction is D. H. Lawrence, who was a man of genius. Think of his famous outburst, refusing to believe what science told him about the nature of the moon. "It's no use telling me it's a dead rock in the sky! I *know* it's not."

It is not quite clear what Lawrence, who was a very clever man, thought he was proving: but what is quite clear is that no Renaissance artist, no artist of the Enlightenment, could conceivably have spoken like that. To them, even as a gesture of feeling, it would have been, in the semantic sense, meaningless.

Let us hope that Bronowski and Mazlish will carry the story on and deal with this breakaway into primitivism after their period ends. Of all the intellectual phenomena of the West, this is the one I have found hardest to explain to knowledgeable Russians. For them, of course, the "Western" tradition of Bronowski and Mazlish is the one they would call their own.

The second strength of the book is a flexible and subtle sense of how the intellectual tradition is correlated with conditions of freedom. Freedom is a noble but an elusive term. I sometimes have the fear that in the West we shout it very loud just to fool ourselves. That is a mistake which Bronowski and Mazlish never make. They are not social historians. They are not concerned, as a social historian such as G. M. Trevelyan is concerned, a man less clever than they are but deeply and realistically imaginative, with the rub and wear of individual men hundreds of years ago going from day to day through their individual lives: but they have a very acute intellectual sense of the ironies and paradoxes of history. They are far too sensible to be taken in by romantic myths. It is clear to them, as it ought to be clear to anyone, that in primitive societies (and to a large extent in all pre-industrial societies) the freedom to make choices (in any meaning which we can reasonably give to that phrase) was out of proportion *less* than it is in any contemporary industrial society.

That is fairly obvious: but Bronowski and Mazlish deal with some ironies that are a good deal less obvious. Above all they realize that historical development is neither simple nor easy to explain. For instance, Calvinism was one of the tightest molds into which men have tried to fit their experience. Each soul was either damned or saved, according to the grace of God. Each man was born elect or predestined to hell, and there was nothing he could do about it. What he did in this life didn't give him a chance of salvation, but only served as an indicator of whether he was a sheep or a goat.

No creed could seem more fatalistic and more a denial of freedom. And yet that creed, as Bronowski and Mazlish

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point out with sardonic glee, was in fact one of the most powerful emancipating forces of the 17th century. It turned out to be Calvinists, devoted fanatically to their faith, who fought with passion in England and in the American wilderness for their own belief. Our whole conception of individual freedom owes most of its strength to our Calvinist ancestors. It was they who fought the king, colonized New England and incidentally took a substantial share in 17th-century science.

Our idea of "freedom" didn't come from tolerant chaps who were only too anxious to see each other live in peace. It came from men convinced of predestination, whose immediate response, when they got power, was to establish a theocracy and make everyone else be convinced of predestination too. Of course there were other strains, some of them the result of quite different conflicts, which helped to produce what Americans and Englishmen regard as freedom; but the effect of Calvinism upon history, and the development by which its social direction became completely contrary to its explicit doctrine, is something that Bronowski and Mazlish will not let us forget.

Their third strength is a similar exercise of sense and intellectual suppleness. No one outside one of the more bigoted conventicles doubts that there is a constant interaction of the way a society is moving and the way in which its members think and the subjects they think about. Often the interaction is difficult to pin down in causal terms—which came first, the break-up of the medieval economy or the first stirring of the scientific revolution? But it is silly to deny the materialist insights and not let them take us as far as they can. For instance, the growth of the West European sea-borne empires between 1500 and 1700 was inseparably linked with the breakthrough in astronomy. One has to be ludicrously frightened of the shadow of Marx not to see earthy roots for the major transformations in scientific history. I am sometimes irritated that the West is so nervous of Marxist thought that we are unconsciously obfuscating ourselves.

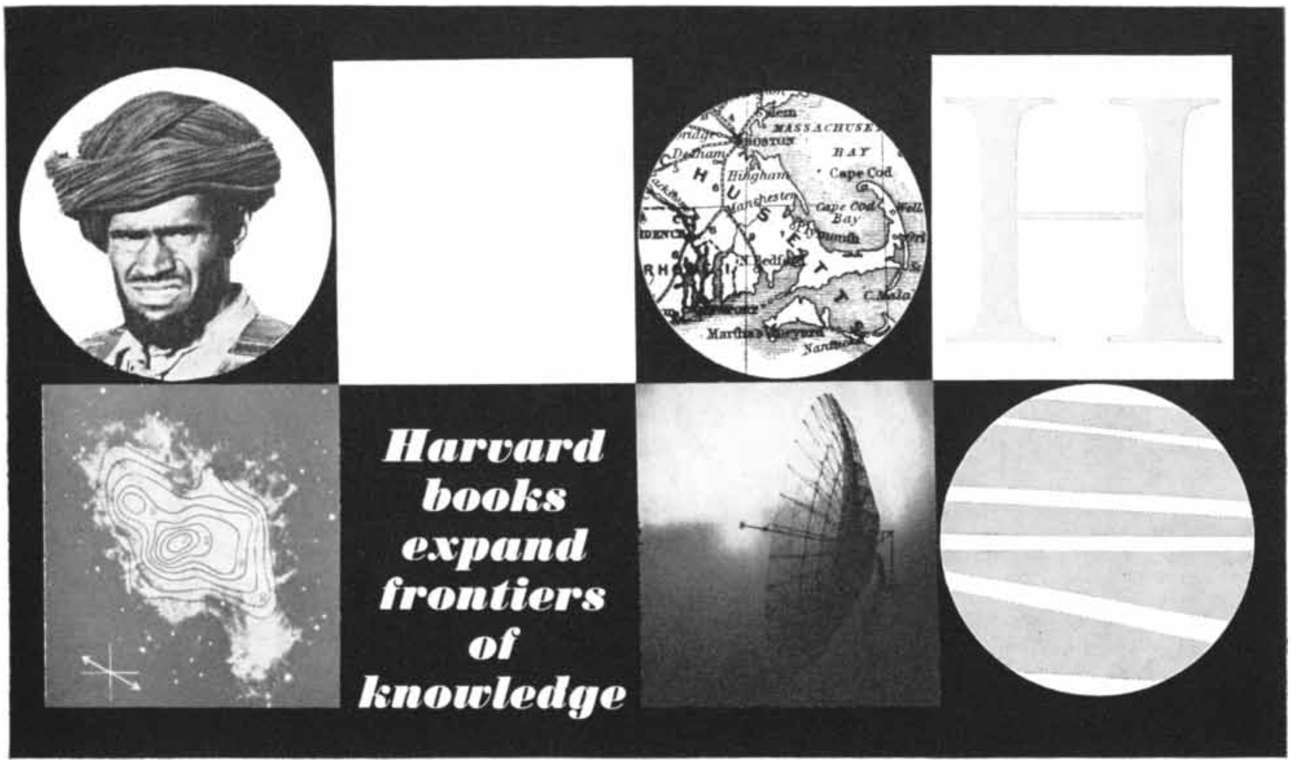
Bronowski and Mazlish are, of course, too balanced to fall into this sin of doctrinal omission, which is one of the contemporary intellectual malaises of the West. On the other hand, they are also too balanced to fall into the corresponding intellectual malaise of the East, which is to believe that every scientific development has in detail a direct materialist one-to-one cause and starting point.

The truth is more complex and needs a good deal of intellectual nerve and constant intellectual vigilance even to begin to grasp. Perhaps the best feature of this book is that the authors possess, more than most men, precisely that mixture of nerve and vigilance.

Their position I am going to put into my own words, and if I am misrepresenting it, I am ready to take the position as my own. It is this. With a good many qualifications, and some reserves about the meaning of social causality, it is both possible and useful to say that the major quantum-jumps in scientific or philosophical thought reflect and are part of material changes in society. That is, it wasn't an accident that the wonderful series Copernicus—Kepler—Galileo—Newton carved out a new scientific universe just as the seaborne empires were being built. It wasn't an accident that the Royal Society sprang into active life precisely at the time that England was becoming the major trading country in the world. It wasn't an accident that, in the adolescence of the industrial revolution, Faraday should discover, and Clerk Maxwell should so beautifully symbolize, a revolutionary source of power. All that is really self-evident. It couldn't be otherwise unless one believes that all thought takes place at random, and that all scientific discovery is just a matter of unrelated "brain waves," as the English used to say, taking place in some limbo outside of history and outside of society. (Incidentally a certain amount of modern thinking and modern art seems to hanker after just that state.)

But that is not the end of it. Grant the major connection between thinking and social change—there is still an inner history of the way the thinking goes. I think Bronowski and Mazlish would argue, and I certainly should myself, that there is an *inner dynamic* of intellectual processes, which is determined in detail by personal accidents, by the talents available at the time of discovery and by the nature of the subject itself. To understand this inner dynamic one must have a professional knowledge of, and a love for, the particular subject. One of the joys of this book is that the authors between them command expertness upon a whole set of intellectual activities, and have never lost their zest for the detail: so that in poetry, in mathematics, in physical science, in philosophy, we are time and time again given passionate insights into what the inner dynamic must have been.

Before I leave this distinction between long-term social causation and the inner



Tribes of the Sahara

By Lloyd Cabot Briggs. An expert who has lived in North Africa for many years describes the problems of the nomadic and sedentary people of the Sahara. He writes of the historical forces that have shaped the culture, language, diet, and mores in this fascinating, strife-torn land. 16 pages of photographs. Glossary. Maps. $6.00

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Edited by Donald H. Menzel. This survey and introduction to further specialized work, was developed from papers presented at a Conference on Radio Noise held at Harvard College Observatory. Expert contributions include: *Man-made Radio Noise, Radio Noise from Meteors, Solar Radio Interference, Noise of Planetary Origin,* and *Cosmic Radio Noise.* 64 figures. $7.50

Cosmic Radio Waves

By I. S. Shklovsky. Translated by Richard B. Rodman and Carlos M. Varsavsky. This first study of radio wave emission from objects located far beyond the solar system examines the influence of radio astronomy on such problems as the nature of primary cosmic rays, the dynamics of the stellar system, and theories of cosmology. 205 illustrations. $12.50

The American Civil Engineer

ORIGIN AND CONFLICT

By Daniel H. Calhoun. A fascinating account of the profession's growth from the late 1700's to the 1840's – tracing the engineer's efforts for professional, social, and economic status during the building of America's first bridges, canals, and railroads. Distributed for the Technology Press of M.I.T. $5.50

Automatic Language Translation

By Anthony G. Oettinger. Foreword by Joshua Whatnough. A brilliant description of the compilation and operation of the Russian to English Harvard Automatic Dictionary – the lexical and technical questions involved – and the proposed transition from automatic dictionary to automatic translator. 144 linecuts. 1 halftone. $10.00

Vibrations from Blasting Rock

By Don Leet. A practical guide covering all aspects of vibrations generated by explosives, from a discussion of the relevant characteristics of the rock to be blasted to the complicated sequence of events following detonation. This information is to be found in no other book. 31 halftones. 39 linecuts. $4.75

The Strategy of Conflict

By Thomas C. Schelling. This book applies variable-sum game theory to political, social, and personal situations – the cold war, industrial strikes, disciplining children, traffic jams, –and analyzes various moves that can be made to resolve these "mutual interest" conflicts. Tables and figures. $6.25

Disease and the Advancement of Basic Science

Edited by Henry K. Beecher, M.D. Twenty-one physicians and scientists discuss the university hospital, and the superior conditions it offers for scientific discoveries dependent on the direct study of disease. Among the distinguished contributors are Linus Pauling, Alexander G. Beard, John F. Enders, Carl F. Cori, Frederick J. Stare, and David G. Cogan. 44 halftones. 39 linecuts. $12.50

The Economics of Defense in the Nuclear Age

By Charles J. Hitch and Roland N. McKean. In showing how economic analysis can make an effective contribution to the formulation of defense policies, the authors stress the implications of the continuing revolution in defense technology and the continuing problems of shaping and reshaping strategic forces. A Rand Corporation Study. Illustrated. $9.50

At your bookseller HARVARD UNIVERSITY PRESS dynamic, the large-scale and the fine-scale, I should like to give one example, which, in order not to commit Bronowski and Mazlish too heavily, I will take from outside their period. The first discoveries of non-Euclidean geometries were made, almost simultaneously, by three men working entirely on their own—Gauss, Lobachevski and Bolyai. This sudden revolutionary outburst was, it seems to me, quite obviously more than a chance. I believe it would be possible to trace changes in the climate of society and thought which made this particular discovery occur at that time and no other. That is what I should call the large-scale correlation. Immediately one comes to the fine scale, however, one finds personal and detailed reasons why the discovery was hung up for 30 years—Gauss's timidity, Bolyai's lack of professional power, the miserable behavior of Lobachevski's colleagues. Finally, it was owing to the special quality and nature of Riemann's genius that, when the non-Euclidean geometries broke into the light again, their exploration took the form it did.

The Western Intellectual Tradition is full of examples of that balance between the cross forces of history and the individual human chances. It is a most eloquent and lively book, and one of the most stimulating for years past. We all ought to be grateful that it has been written.

Short Reviews

A Collection of Mathematical Problems, by S. M. Ulam. Interscience Publishers, Inc. ($5). Some years ago, before World War II, the author of this book, together with a number of leading Polish mathematicians then living in Lvov, had a small mathematical club which met almost every day in one of the coffee houses near the university to discuss problems of common interest and to tell one another of their latest work and results. The suggestion was made that the more interesting problems be recorded, and so a large notebook was purchased and deposited with the headwaiter of the "Scottish Coffee House," who, upon demand, would bring it out of some secure hiding place, leave it at the table, and after the guests departed, return it to its secret location. The storm which swept over Europe spared neither the city of Lvov, its mathematicians nor the "Scottish Book" (as it came to be called). First the Russians occupied the city, and certain of their mathematicians must have visited the very coffee house, for at the end of the Scottish Book they entered several problems (and even left prizes for their solution). The Germans were less kind. When they occupied the town, they killed a number of mathematicians, among tens of thousands of other Poles. The Scottish Book disappeared; in fact it was spirited away by one of the survivors and may have been buried, as had been agreed beforehand, near the goal post of a football field outside the city. At any rate, it survived. A typewritten copy was sent after the war by the mathematician Hugo Steinhaus to Ulam, and he had mimeographed copies made which were distributed to, and widely appreciated by, a number of U. S. mathematicians and physicists. Many of the problems in the Scottish Book appear in the present volume, but the greater part of the material is of later origin. There are questions, suggestions, matters not fully worked out. The problems deal with set theory, higher algebra, topology, group theory, theoretical physics, computing machines. A heady, difficult and challenging collection.

The Birth of a New Physics, by I. Bernard Cohen. Doubleday & Company, Inc. (95 cents). This small paperback, a survey of the development from Copernicus to Newton of the single most important idea in physics—the dynamics of motion—is the first volume in the M.I.T. Science Study Series that fully meets its announced purpose, and the best book by far that Cohen has written. With clarity, patience and skill he traces the revolutionary transformation in physics from Aristotle's "commonsense," "natural-motion" system, through the Copernican innovations, the brilliant explorations of Galileo and Kepler's extraordinary inspirations to the culminating grand design of Isaac Newton. The explanation of Galileo's work, in particular his discovery of the correct law of freely falling bodies, is one of the high points of an outstanding book. Physics students and the general reader interested in the sublimely erratic growth of ideas will find delight in these pages.

Electromagnetism and Relativity, with Particular Reference to Moving Media and Electromagnetic Induction, by E. G. Cullwick. Longmans, Green & Co., Inc. ($12.50). The principal change in the second edition of this book, the first edition of which was reviewed in Scientific American in 1958, is the treatment of the controversial and endlessly intriguing clock paradox of the special theory of relativity. Earlier the author took the position that

both the paradox and its solution are fallacious. On reconsideration he now concludes that relativity theory "goes far beyond the limits warranted by established facts." It may be that the misbehavior of clocks can be explained by the general theory of relativity, by postulating an effect due to a difference of gravitational potential, but the effect has not yet been demonstrated; besides which the argument has been made that the paradox can and should be solved by the special theory alone. Cullwick's view is that the purpose of the Lorentz transformations is to make Maxwell's electromagnetic-ether theory conform with the principle of relativity of inertial systems, and it has not been established by experiment that the transformation has any relevance outside electromagnetism. It becomes clear then, he says, that when we illustrate the Lorentz transformation by means of moving rods and clocks, we are divorcing it from its true context: electromagnetism. "For example, according to the Special Theory, the velocity of a body relative to the observer can never exceed that of light, and this is certainly true of charged particles accelerated from rest in the reference system. But the conclusion that it must necessarily apply to all bodies remains speculative and unverified, as does the contraction of a moving rod or the slow rate of a moving mechanical clock."

MOVING ENVELOPES OF STARS, by V. V. Sobolev. Harvard University Press ($4.75). Certain stars which have rapidly changing bright-line spectra eject vast quantities of matter, either in explosive processes or more or less contінously during a long interval, in which case extensive atmospheres are formed. These atmospheres are of great interest to astronomers, not only because of the extreme conditions in the "envelopes" themselves, but also because the phenomena yield information about the nature of the stars—the energy they radiate in different regions of the spectrum, the forces they exert on the envelopes and so on. The present volume is a translation from the Russian by Sergei Gaposchkin of what is regarded as a path-breaking work on the theory of radiative equilibrium of a moving medium, applied to the moving envelopes of stars.

BERTRAND RUSSELL SPEAKS HIS MIND. World Publishing Company ($3.50). Thirteen unrehearsed television dialogues between Russell and Woodrow Wyatt (at the time a British Broadcasting Corporation television commentator and currently a Labour member of

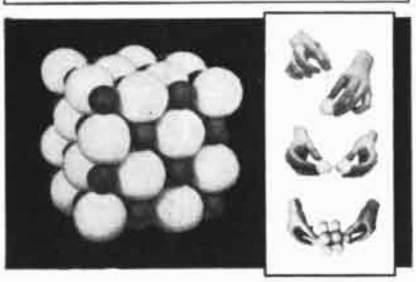
Parliament) on a variety of topics: philosophy, religion; war and pacifism, communism and capitalism, power, happiness, nationalism, the H-bomb and so on. At times a little thin and TV-ish, but over-all characteristically pungent, wise and delectable.

HEAVENLY CLOCKWORK: THE GREAT ASTRONOMICAL CLOCKS OF MEDIEVAL CHINA, by Joseph Needham, Wang Ling and Derek J. de Solla Price. Cambridge University Press ($12.50). The improvement of measuring instruments was one of the essential conditions in the rise of modern science and technology, and, in particular, the invention of the mechanical clock is acknowledged to have been a decisive advance. When did it happen? Until recently the accepted view was that the big jump from sundials and water clocks to a mechanism which, by means of a controlled, rotating wheel, would keep pace with the apparent daily turning of the heavens was made in Europe in the early 14th century. The main trick, of course, was to slow the wheel so as to make it keep a constant speed, and the solution came in the form of the verge-and-foliot escapement fitted to a weight-driven mechanism. (An escapement is a device for controlling the rate of revolution of the wheel by periodically arresting its motive power, which stems from a spring, falling weight or other source.) The accepted view has, however, been severely jolted by the recent researches reported in this book. While engaged in studies connected with their magnificent multivolume history of Chinese science and civilization, Needham and Wang chanced upon ancient texts which indicated that the European innovation of mechanical timekeepers had been anticipated in China some six centuries before. In collaboration with Derek Price, a historian of astronomical instruments, Needham and Wang undertook the translation and interpretation of key portions of the *Hsin I Hsiang Fa Yao* (New Design for a Mechanized Armillary Sphere and Celestial Globe), written in A.D. 1090 by Su Sung, which describes in meticulous detail a 30-foot-high astronomical clock tower, “surmounted by a huge bronze power-driven armillary sphere for observation, and containing, in a chamber within, an automatically rotated celestial globe with which the observed places of the heavenly bodies could be compared. On the front of the tower was a pagoda structure with five storeys, each having a door through which manikins and jacks appeared ringing bells and gongs and holding tablets to indicate the hours and other special times of the day and night." The motive source of this spectacular contraption, housed in the tower, was in itself not spectacular. It consisted of a great scoop-wheel using water flowing from a constant-level tank (to which the water had been raised by hand-operated norias) which turned all the shafts working the various devices. But there was genius in this creaking, splashing, clanging engine: the wheel was checked by an escapement consisting of a pair of balancing levers, the upper of which had a checking fork, so arranged that the descending scoop in the process of filling was held in place until it was full; then it would, by a parallel linkage, trip the upper lever. This action pulled down a chain connected with another lever, thus releasing a lock that arrested the forward motion of the wheel so that it could now rotate to the next notch and bring the next scoop into position to be filled. By shifting the weights on the balancing levers and by other adjustments, the speed of rotation—and thus the time-keeping accuracy of the clock—could be effectively regulated; it is said to have worked for many years before being carried away into exile. Having mastered Sung's text, the authors were led to explore farther back in a history of Chinese horology, and they discovered that the first of such escapements had been devised in A.D. 725 by a Buddhist monk and a military official. Another feature of Su Sung's clock, perhaps even more remarkable than the escapement, is a "celestial ladder," or endless chain drive, a mechanism which, though sketches of it had been made by Leonardo da Vinci and others, did not in fact come into use in Europe until the 19th century. Besides presenting the translation of Su Sung's text, a lucid explanation of the clock's working and a historical account of its background, the authors trace the development of clockwork after Su Sung, discuss its social context and sketch the general history and transmission of astronomical clocks to later times. The book is beautifully finished in Cambridge's best style and superbly illustrated with pictures from old Chinese texts, with plates and freshly drawn figures and working drawings; there is also a full glossary, a bibliography and a formidable apparatus of footnotes, some of which hold nuggets of fascinating technical information (*e.g.*, in a modern watch, as a result of the escapement, the wheels are motionless for 19/20 of each second). One small criticism: Because of his justifiable enthusiasm over the importance of Chinese science, and perhaps as a reaction to the ignorance and long neglect of it by Western historians, Needham is occasionally inclined to make too much of priority, to exaggerate what is already so wonderful that it scarcely requires exaggeration.

PHOTOGRAPHIC LUNAR ATLAS, edited by G. P. Kuiper, with the collaboration of D. W. G. Arthur, E. Moore, J. W. Tapscott and E. A. Whitaker. University of Chicago Press ($30). This superb atlas presents the surface record of the moon by selected photographs taken at five observatories: Mount Wilson, Lick, McDonald, Yerkes and Pic du Midi. The best resolution obtained is about .4 second of arc, corresponding to about half a mile. Arranged so that it can be readily used at the telescope, the atlas is divided into three parts: an introduction of 11 sheets showing the subdivisions of the lunar surface into 44 fields and giving the names of the maria, mountain ranges and craters; 176 sheets, comprising the main body of the atlas, plus eight sheets for the four polar areas; 35 supplementary sheets giving additional coverage of the 44 fields. Five future supplements are planned or in preparation.

COVERED BRIDGES OF THE NORTHEAST, by Richard Sanders Allen. Stephen Greene Press ($5.95). COVERED BRIDGES OF THE MIDDLE ATLANTIC STATES, by Richard Sanders Allen. Stephen Greene Press ($6.50). These two attractive volumes tell the story of covered bridges—those that once stood and those that still remain—in an engaging text supported by hundreds of illustrations. Allen explains how the bridges were made, describes their history in war and peace and provides a comprehensive census of existing bridges. In case you have always wanted to know why bridges were covered: Not to protect the user, his horse or his hay; nor to keep a neurotic horse from being frightened by the glint of water; nor to keep snow off the floor; nor "to prevent a traveler's knowing what kind of town he was approaching until it was too late to turn back"; but, for one and only one reason, to protect the wooden skeleton—the supporting sides or trusses—from moisture, and thus preserve the bridge itself. Simple but effective.

THE STRATEGY OF CONFLICT, by Thomas C. Schelling. Harvard University Press ($6.25). The author of this series of essays, a Harvard economist who spent some time at the Rand Corporation, proposes to show that there are



"enlightening similarities" between "maneuvering in limited war" and "traffic-jam jockeying," between "deterring the Russians and deterring one's own children" and between the "modern balance of terror and the ancient institute of hostages." The theory of games, he says, is potentially a useful technique for handling cold-war strategy, Russians and the balance of terror. He then sets out to prove this thesis. His book is wordy and full of solemn commonplaces solemnly arrived at; it takes for granted a host of psychological truisms which are doubtfully true; it leaves the reader with the impression that anyone who takes the author's position seriously and permits game theory to be his guide, so far from being likely to outmaneuver the Russians, will be lucky if he doesn't get run over.

STUDIES IN EARLY PETROLEUM HISTORY, by R. J. Forbes. E. J. Brill ($8.50). MORE STUDIES IN EARLY PETROLEUM HISTORY 1860-1880, by R. J. Forbes. E. J. Brill ($10). In his monographs on the history of technology the assiduous Dr. Forbes never disappoints us; he uncovers fresh, out-of-the-way facts and re-creates forgotten arts and crafts. In the first of these volumes he discusses the oil seepages of Europe, the medieval medicinal uses of petroleum and its application to lighting and lubrication, the beginnings of the petroleum industry, the uses of bitumen in the Orient, the discovery of oil in the New World, "pouring oil on troubled waters" (a procedure mentioned by Pliny in 79 B.C. and rediscovered by Benjamin Franklin). The second volume contains essays on the chemist's attempts to establish the constituents of crude oils, the use of naphtha in warfare, 19th-century oil production in eastern Europe, new types of oil lamps as a factor in the rise of the petroleum industry, wax candles, the use of the by-products of naphtha and the manufacture of kerosene for burners, bearings and bitumens. Excellent illustrations.

RADIATION, GENES AND MAN, by Bruce Wallace and Th. Dobzhansky. Henry Holt and Company ($4.75). The authors give a sound background sketch of genetics, then discuss the induction of mutation by radiation and the genetic effects of radiation on man. Their conclusions are restrained, and they are so anxious to be fair to both sides in the fallout controversy that they bring themselves to recommend not only books by Linus Pauling and Ralph Lapp but also one by Edward Teller. There is no mis-

taking, however, where their hearts lie. For the general reader as well as the biologist.

An Introduction to Scientific Research, by E. Bright Wilson, Jr. McGraw-Hill Book Company, Inc. ($2.95). Wilson's book, published in 1952, which appears here as a paperback, imparts clearly a number of principles, maxims, procedures and general techniques useful to the practicing scientist. Among the topics are the uses of scientific literature, the elements of scientific method, the design of experiments and apparatus, measurement and the errors of measurement, the analysis of experimental data, probability, mathematical methods.

The Book of Sports Cars, by Charles Lam Markmann and Mark Sherwin. G. P. Putnam's Sons ($15). This richly illustrated volume will cause sports-car lovers both to dance in the streets and to pine away with longing for the treasures they cannot possess. It describes 60 years of dual-purpose sports motoring: the great cars made in Britain, France, the U. S., Italy, Germany, Belgium, Austria; the famous builders such as Allard, Bentley, Bugatti, Cunningham, de Dion, Duesenberg, Ferrari, Lancia, Healey, the Maserati brothers, Porsche, Stutz, Voisin; the celebrated male and female drivers, including the Bentley boys, Fagioli, Fangio, Hawthorn, Moss, Nuvolari, Camille du Gast, Gwenda Hawkes, Dorothy Levitt, Kay Petre, Denise McCluggage, Elsie Wisdom; the major races, rallies and hill-climbs. A satisfying volume.

Physics, the Pioneer Science, by Lloyd W. Taylor. Dover Publications, Inc. ($4). A two-volume paper-back reissue of a first-class elementary physics text which was published in 1941 and unaccountably permitted to go out of print. Taylor's book is the best of its kind in placing classical physics in its historical setting, in providing biographical information and excerpts from original writings.

Britain's Scientific and Technological Manpower, by George Louis Payne. Stanford University Press ($8.50). A study, prepared at the request of the President's Committee on Scientists and Engineers, of what Britain is doing to meet the increasing need for scientists and engineers. Among the topics of major interest are the dimensions of the problem, the response of secondary schools and universities and the social consequences of technological expansion.

THE SENSES, by Wolfgang von Buddenbrock; EBB AND FLOW, by Albert Defant; THE ANTS, by Wilhelm Goetsch; THE BIRDS, by Oskar and Katharina Heinroth; THE SUN, by Karl Kiepenheuer; THE STARS, by W. Kruse and W. Dieckvoss; ANIMAL CAMOUFLAGE, by Adolf Portmann; LIGHT VISIBLE AND INVISIBLE, by Edward Ruechardt; PLANET EARTH, by Karl Stumpff; VIRUS, by Wolfhard Weidel. University of Michigan Press ($1.95 each). Paperback reprints of a series of short, authoritative, attractively illustrated popularizations, several of which received favorable notice in these columns on their first appearance. In hard cover these books of well under 200 pages were much too expensive; in their present format they still cost too much, but at least students and average buyers will feel they can afford them.

AMERICAN BUILDING ART: THE NINETEENTH CENTURY, by Carl W. Condit. Oxford University Press ($12.50). A survey of building techniques in the U. S. in the 19th century—a subsequent volume is to cover the 20th century—including wood and iron framing, wooden and iron bridge-trusses, suspension bridges, iron arch bridges, train sheds, concrete construction. The details regarding columns, arches, beams, bending moments, trusses and the like are of course essential to such an account, but here they get the better of the author, who insists on treating each category separately, completely and chronologically before taking up the next one, with the result that he produces a sound but plodding history in which the evolution of the building art as a whole—an exciting story—never comes into view. Bibliography and illustrations.

COMPLETE FIELD GUIDE TO AMERICAN WILDLIFE, EAST, CENTRAL AND NORTH, by Henry Hill Collins, Jr. Harper & Brothers ($6.95). This handbook gives details as to appearance, habitat, habits and food of all species of birds, mammals, reptiles, amphibians, food and game fish and principal marine invertebrates occurring annually in North America east of the Rockies and north of the 37th parallel. Illustrations in black and white and color, useful range maps and a full index.

THE OTHER SIDE OF THE MOON. Pergamon Press ($2.50). This volume, issued by the U.S.S.R. Academy of Sci-

Dr. V. G. Szebehely speaks from a wealth of personal experience when he describes the atmosphere of Space Sciences Laboratory as "highly academic." Before joining General Electric he served as Professor of Applied Mechanics and Mathematics in universities and colleges both in this country and abroad. He has published more than 60 papers, the most recent of which, "Equations for Thrust Programs," was prepared for the XI Congress of the International Astronautical Federation, Stockholm, August 17, 1960.

ences and translated by J. B. Sykes, contains a brief account of the epochal photographing of the other side of the moon in 1959 by the Soviets' third space rocket and of the apparatus itself, as well as the three now famous photographs taken from the rocket in a 40-minute period on October 7, 1959.

War in the Modern World, by Theodore Ropp. Duke University Press ($10). A scholarly, thoughtful and well-written survey of the evolution of warfare from the "age of the captains" to the "age of violence." The main stress is on the wars of the 20th century and on the effect of political, social and economic circumstances on the theory and practice of the military profession.

The Etiology of Schizophrenia, edited by Don D. Jackson. Basic Books, Inc. ($7.50). A co-operative volume whose papers attempt to present what is today known about the genesis of schizophrenia—a disease that afflicts nearly a quarter of the persons admitted to public mental hospitals. Genetic, biochemical, psychological, physiological and cultural factors are considered.

Notes

The Biochemistry of Development, by Jean Brachet. Pergamon Press ($10). This monograph introduces recent advances in the field of chemical embryology: in problems of gametogenesis, fertilization, cleavage, embryology of vertebrate and invertebrate eggs, the biochemistry of differentiation.

Electrons and Phonons: The Theory of Transport Phenomena in Solids, by J. M. Ziman. Oxford University Press ($13.45). A treatise on the theory of electrical and thermal conduction in metals, semiconductors and insulators, giving the experimental facts and their theoretical underpinning.

The Scattering and Diffraction of Waves, by Ronold W. P. King and Tai Tsun Wu. Harvard University Press ($6). This volume in the Harvard Monographs in Applied Science is a summary of research carried out primarily at the University in those aspects of diffraction and scattering that properly fall under the broad heading of reflections from surfaces of complex shape.

A Guide to Planets, by Patrick Moore. W. W. Norton and Company, Inc. ($6.50). Revised edition of an informative book, incorporating recent

advances in lunar and planetary astronomy. Illustrations.

SCIENTIFIC EXPLANATION: A STUDY OF THE FUNCTION OF THEORY, PROBABILITY AND LAW IN SCIENCE, by Roland Bevan Braithwaite. Harper Torchbooks ($1.85). Soft-cover reprint of a probing and stimulating account of the logic of scientific explanation—the function of theory, probability and law—which was reviewed at length in these columns some five years ago.

QUANTUM ELECTRONICS, edited by Charles H. Townes. Columbia University Press ($15). A symposium consisting of papers and discussion at a conference on quantum electronics phenomena held in New York in 1959.

CULTURE AND MENTAL HEALTH, CROSS-CULTURAL STUDIES, edited by Marvin K. Opler. The Macmillan Company ($8.75). The editor has gathered papers representing the several behavioral sciences, which are concerned with the variable effect of culture or cultural stress on mental health. The material deals with the American Indian, people of the South Pacific, Asia, Africa, Britain and the U. S.

TICKS: A MONOGRAPH OF THE IXODOIDEA. PART V: ON THE GENERA DERMACENTOR, ANOCENTOR, COSMIOMMA, BOOPHILUS & MARGAROPUS, by Don R. Arthur. Cambridge University Press ($11.50). This volume continues a classic work on ticks by G. H. F. Nuttall and his co-workers C. Warburton, W. F. Cooper and L. E. Robinson, which was begun in 1908, was issued in four parts, but remained unfinished when Nuttall died in 1937. Two further parts are planned.

PSYCHOLOGY OF MUSIC, by Carl E. Seashore. McGraw-Hill Book Company, Inc. ($2.95). An inexpensive soft-cover reissue of Seashore's notable study (first published in 1938) of the psychology of music: the features of the musical mind, the science of music, learning and thinking in music, the character of musical talent, the properties of the leading instruments, the measure and inheritance of musical talent, the development of musical skills. Illustrations and bibliography.

AN INTRODUCTION TO SOCIAL BIOLOGY, by Alan Dale. Charles C. Thomas ($6.50). Third, revised edition of an interesting British text that deals with the social and economic problems rooted in

the facts of applied biology. This is a good book for liberal-arts students, who often omit taking any course in biology because it is too special for them, or for courses in adult education.

THE FORESEEABLE FUTURE, by Sir George Thomson. The Viking Press, Inc. (95 cents). Thomson's engaging peek at 100 years from now, reviewed at length in this magazine on first publication in 1955, is now offered in a nicely made paperback.

PROGRESS IN NUCLEAR ENERGY: Series I, PHYSICS AND MATHEMATICS, Vol. III, edited by Donald J. Hughes, J. E. Sanders and J. Horowitz. Pergamon Press, Inc. ($15). A selection of papers presented at the Second UN Conference on the Peaceful Uses of Atomic Energy.

THE MATH ENTERTAINER, by Philip Heafford. Emerson Books, Inc. ($2.95). A collection of mathemathical knickknacks: conundrums, anecdotes, tricks, problems, crossword puzzles. Amusing.

HOPI KACHINA DOLLS, by Harold S. Colton. University of New Mexico Press ($8). Revised edition of a little volume which describes the meanings, manufacture and principal features of the Hopi Indians' delightful carved and painted dolls, given to the children of the tribe so that they may learn to recognize and respect the participants in the ritual of Kachina dances. Errors have been corrected and additional Kachinas added.

THE WORLD AS WILL AND REPRESENTATION, by Arthur Schopenhauer. The Falcon's Wing Press ($17.50). A new, unabridged translation from the German, by E. F. J. Payne, of Schopenhauer's famous philosophical work, first published in 1818.

STUDIES IN PHILOSOPHY AND SCIENCE, by Morris R. Cohen. Frederick Ungar Publishing Co. ($4.50). A reissue of the last collection of Morris Cohen's essays.

MEN OF SCIENCE IN AMERICA, by Bernard Jaffe. Simon and Schuster, Inc. ($6.95). A new edition, with a biography of Enrico Fermi and new opening and closing chapters, of a readable and enlightened account of outstanding men in American science from Colonial times to the present.

ORTHOGONAL POLYNOMIALS, by Gabor Szegö. American Mathematical Society ($10.60). Revised and augmented edi-

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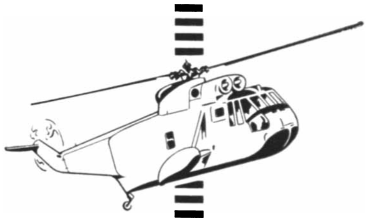

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tion of a 1939 monograph on a mathematical subject closely related to many important branches of analysis.

APPLIED GEOGRAPHY, by L. Dudley Stamp. Pelican Books (95 cents). A noted British geographer applies the principles of geographical survey and analysis to the problems of Britain today: population, land use, land planning, town and country planning, climatology, industrial patterns and so on.

HUMAN BIOCHEMICAL GENETICS, by H. Harris. Cambridge University Press ($7). This book reviews present knowledge of human inherited metabolic abnormalities, a rapidly growing field of study which draws its material from medicine, genetics, biochemistry, chemical pathology and anthropology.

CHEMISTRY OF NUCLEAR POWER, by J. K. Dawson and G. Long. Philosophical Library ($10). Two Harwell scientists describe the chemist's contribution to the over-all atomic energy program.

PROGRESS IN NUCLEAR PHYSICS, edited by O. R. Frisch. Pergamon Press, Inc. ($14). Volume VII in this series contains articles on the bubble chamber, resonance fluorescence in nuclei, spallation, an optical model for nuclear scattering, weak interactions.

MAN, CULTURE, AND SOCIETY, edited by Harry L. Shapiro. Oxford University Press ($2.25). Reissue in paper covers of an instructive collection of essays on general anthropology.

PRINCIPLES OF ANIMAL VIROLOGY, by F. M. Burnet. Academic Press, Inc. ($12). In the second edition of this book nearly half the text of the first edition has been replaced, and other changes have been made.

THE INTERNAL-COMBUSTION ENGINE IN THEORY AND PRACTICE: VOLUME I, by Charles Fayette Taylor. John Wiley & Sons, Inc. ($16). The first volume of a projected two-volume work dealing with thermodynamics, fluid flow and performance in existing types of internal-combustion engines.

VOYAGES TO THE MOON, by Marjorie Hope Nicolson. The Macmillan Company ($1.75). Illustrated paper-back reissue of Miss Nicolson's scholarly and readable survey of early adventures in imagination about supernatural voyages, flying chariots, wanton wings and other aerial acrobatics. A palatable item.

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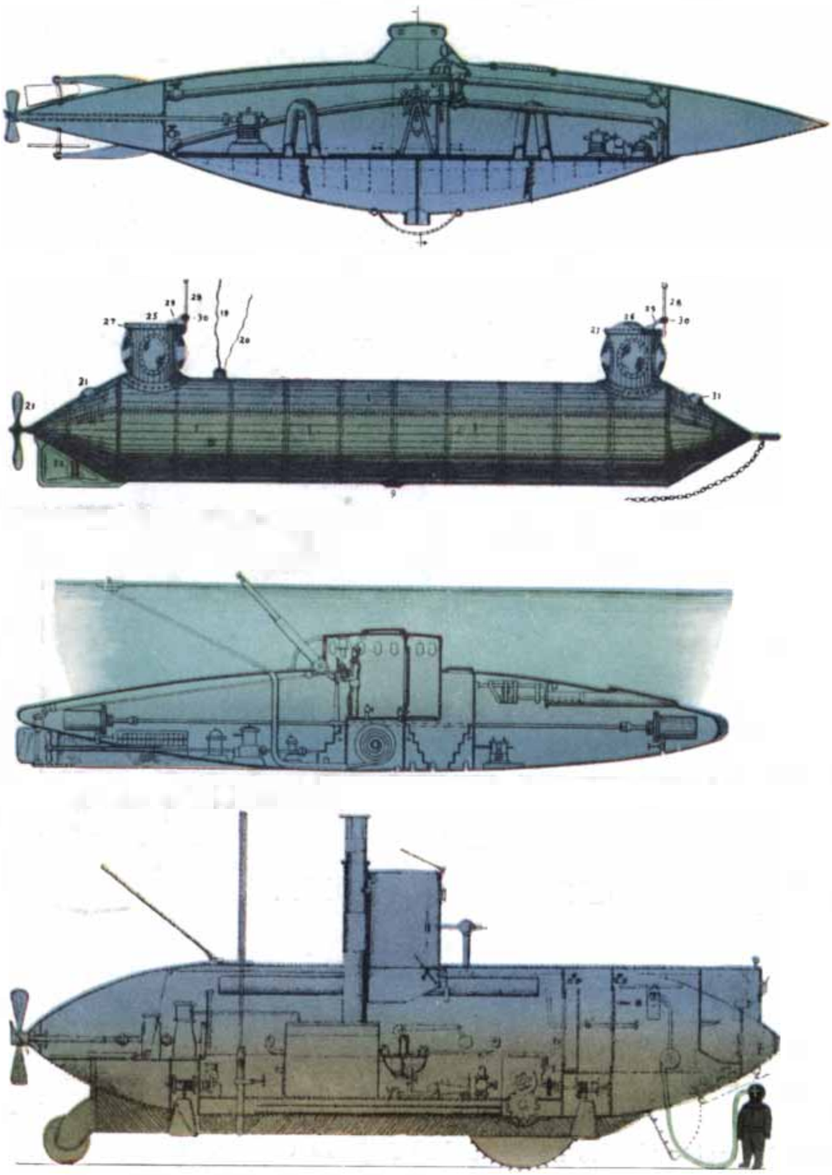

"The Crew Sang, Played Cards, Caught Clams"

In 1960, the *USS Triton* circumnavigated the globe undersea, and the *USS George Washington* successfully fired the Polaris missile while submerged. Both these nuclear submarines were designed and built by Electric Boat. In 1897 the *Holland*, the United States Navy's first submarine, was launched by the John P. Holland Torpedo Boat Company, predecessor of Electric Boat. Before the submarine won recognition as a naval weapon, there had been at least a hundred years of experimentation with submersibles. Bushnell's *Turtle* futilely attacked British warships during the Revolution. The Confederate submarine *Hunley* went down off Fort Sumter with her one victim, the frigate *Housatonic*. Simon Lake's wheeled *Argonaut* of 1897 explored the bottom of Chesapeake Bay while the crew sang, played cards, caught clams.

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