SCIENTIFIC AMERICAN

HOME LIFE OF THE SWIFT

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July 1954

More jobs – through science

From the earth, air, and water come new things for all of us—and new jobs

The elements of nature are a limitless frontier, a continuing challenge to science. Out of them, scientists are developing new materials that benefit us all in many ways.

A CHEMICAL A MONTH—The scientists of Union Carbide, for example, have introduced an average of *one new chemical per month for over twenty-five years.*

Some of these have led to the growth of important industries, such as plastics and man-made textiles. This, in turn, has meant more opportunities, more jobs—in construction, manufacturing, engineering and sales, as well as in research.

IN OTHER FIELDS, TOO, the people of Union Carbide have helped open new areas of benefit and opportunity. Their alloy metals make possible stainless and other fine steels; the oxygen they produce helps the sick and is essential to the metalworker; their carbon products serve the steelmakers and power your flashlight.

PROGRESS THROUGH RESEARCH—Union Carbide has 23 research and development laboratories constantly working in major fields of science to continue this record of product development—and more jobs through science.

FREE: *Learn how Alloys, Carbons, Gases, Chemicals, and Plastics improve many things that you use. Ask for "Products and Processes" booklet E.*

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In Canada: **Union Carbide Canada Limited**

UCC's Trade-marked Products include

Synthetic Organic Chemicals
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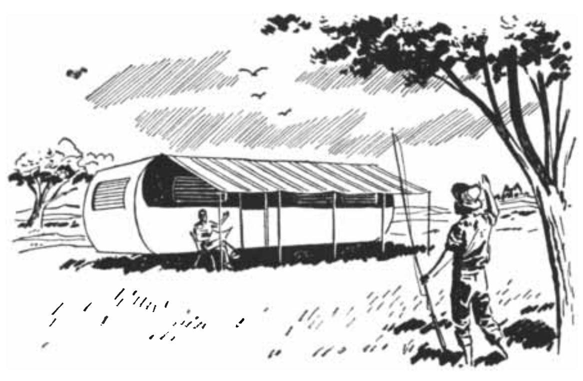
Prestone Anti-Freeze
Haynes Stellite Alloys
Union Carbide
Prest-O-Lite Acetylene
Linde Oxygen
National Carbons
Acheson Electrodes

BUSINESS IN MOTION

To our Colleagues in American Business . . .

Many of the millions of people who travel and live in trailers follow a somewhat regular routine. They trek south for the winter, and stay put for months. Then they motor north to a summer place. South or north, they have a need for awnings. You would not think that there would be any special opportunity for improvement in awnings for trailers, yet Revere and an awning manufacturer found one.

These awnings have to be demountable, storable in small space during transit, and of course should be light. An awning maker had been making rafters out of steel tube, in sizes to permit telescoping to save space. Could we save weight without sacrificing strength by supplying aluminum tube? We knew we could, since there is an aluminum tube that is as strong as the steel tube that was being used.



After a careful analysis of the requirements, specifications were set up, and a sample order placed. The specifications included not only the strength of the tube, but also careful control of dimensions, so the two sizes would mate for telescoping, with clearances that would be close, yet not too tight to present problems to the trailer owner.

The sample aluminum tube order was thoroughly checked in manufacture, then tested mechanically for strength and for ease of handling in a trailer park. The aluminum rafters made of this tube proved to be easily fabricated, and they withstood the loads imposed by wind and rain. They are much lighter, look much better, and the customer reports he realizes economies.

An important thing to remember about this case is that Revere makes tube and pipe in copper and copper alloys, in aluminum alloys, and also electric welded steel tube. This presents a wide choice, and makes it possible for us to recommend exactly the metal and form that will best fulfil the needs for each application. Diversification of Revere Products produces benefits for all.

Revere not only makes aluminum tube, but also aluminum extruded shapes, forgings, electrical bar, coiled and flat sheet. In addition, copper and copper alloys in the same and other forms, plus rolled mouldings and lockseam tube in various metals and alloys. The complete list of Revere Products takes a full page. The Revere policy is to collaborate as closely with customers as possible. Sometimes we recommend an item that will cost less per pound than what he has been buying. Sometimes we prove that paying a little more per pound will save important sums in processing and improve product life and appearance. Either way, we try to save money for our customers or enable them to make better products. Most other suppliers to industry have the same attitude and policy, so we suggest you consult with them to add their knowledge and experience to yours, for mutual advantage.

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Founded by Paul Revere in 1801

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LETTERS

Sirs:

Doubtless through inadvertence or lack of complete information, Lawrence P. Lessing's otherwise excellent article on the life of the late Major Edwin H. Armstrong [Scientific American, April] omits certain facts concerning patent interference proceedings and patent litigations. . . .

In the long-contested Interference Proceedings, involving the "feedback" circuit in which Armstrong, Meissner, Langmuir and the writer were involved, priority of invention was finally granted to me, and my two broad "feedback" patents were issued in 1924. However, Armstrong had been granted another patent, the "regenerative circuit" patent under which the Westinghouse and many others were licensed. He now sought . . . an order canceling my two newly issued patents. Simultaneously the De Forest Company brought action . . . to declare the 1914 Armstrong patent on the "regenerative audion" invalid in view of the District of Columbia Federal Court's award of priority. We won our action. Armstrong-Westinghouse lost theirs. They appealed both decisions and lost both.

. . . His regenerative patent having been previously sustained by the New York Federal Court of Appeals, Armstrong now appealed to the Supreme Court. In 1928 that Court sustained me as the originator of the feedback circuit, the conception date being August 12, 1912. However, that decision did not end the 14-year controversy! Armstrong, having recently lost by Patent Office Interference Proceedings his superheterodyne patent to his predecessor and World War I tutor, Lieut. Lucien Levy of France, and his superregenerative receiver patent application to Turner and Logwood, now elected to defend Radio Electric Laboratory, whom the Radio Corporation of America had sued for infringement of my feedback patents. The Federal District Court of Eastern New York . . . found for the plaintiff. The defendant company appealed that decision before the Federal Court of Appeals in New York. There Judge Manton (who later went to the penitentiary) dared reverse the Supreme Court . . . , opining that "the Supreme Court did not understand the true merits of the controversy." The reversal by a Circuit Court judge of the findings of the Supreme Court made the matter a *cause célèbre* among all the annals of patent jurisprudence. For the first time in its long history the same patent had come twice before our Supreme Court, and not for a mere rehearing. This time the Court, in sustaining itself and reversing Manton, handed down a lengthy, masterly worded decision, the work of the late distinguished Justice Cardozo. . . .

Unquestionably the repeated losses of Armstrong's numberless patent suits, following his initial success in the field, exerted a profoundly depressing and enduring effect upon his self-centering character. Notwithstanding his brilliant development of the high-frequency wide-band frequency modulation system, he seemed never content with the mead of good fortune that the Federal Communications Commission awarded him. I found him truculent, never-forgetting, ever resentful. He seemed totally unreconciled to the fact that fate had denied him much that he had fought to achieve. He continued to find new foes to battle, and filed patent suit after patent suit. As the years of his life extended and darkened, more and more gloomy appeared his outlook, until in bitterness he could endure no longer to face a warrior's future.

LEE DE FOREST

Los Angeles, Calif.

Sirs:

In my brief tribute to the life of the great radio inventor, Edwin H. Armstrong, following his tragic suicide, it

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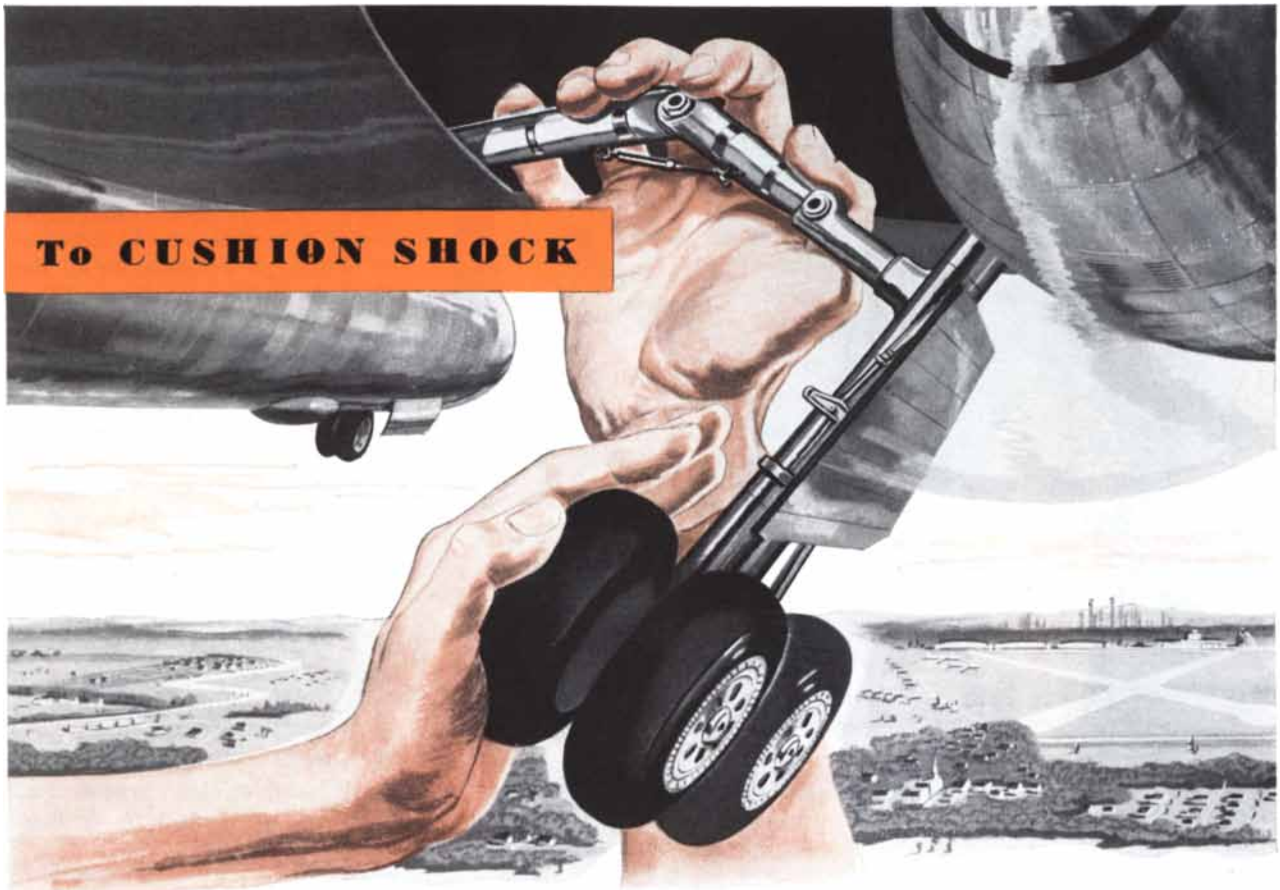

Gentle restraint on a 3-ton knee

keeps a shock absorber from being shocked

It is easy for the big 6600-pound landing gear we build for the B-36 bomber to absorb the impact of the 180-ton aircraft as it lands at 100 miles an hour.

Unfolding the gear for a landing is eased by a small shock absorber which gently cushions the knee of the big shock absorber (aircraft landing gears are just *big* shock absorbers). This restrains the knee from "slamming home" (as engineers term it) when it locks.

If you are plagued by severe shock in machines or apparatus you build, or if tiny flutter in your device tends to build up into large destructive waves, it will pay you to talk with us. Some vibration and impact problems are so complex that they require shock absorbers to cushion the shock absorber. But we believe no impact problem is so complex that it can't be solved. Write for descriptive booklet D-7.

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BALL-SCREW MECHANISMS AIR-OIL IMPACT ABSORBERS
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Combining the screw with balls makes Cleveland Pneumatic's patented ball-screw actuator drive with as little as 10% friction . . . compared to as much as 50% for ordinary screw drives. You can cut the weight of a drive system, reduce its space, lessen its cumbersomeness, increase its control accuracy, and provide pin-point positioning. Let our engineers work out your ideas for our ball-screw actuators.

was hardly germane or possible to follow all the twists and turns of his many patent suits. Dr. de Forest has filled in here, in part, any deficiencies that might exist.

Fortunately, in scientific affairs there are courts higher than even the Supreme Court, where so many considerations other than scientific may be forced into the shaping of decisions. In all these higher courts—meaning the scientific societies of his peers—Armstrong is officially recognized, despite the Supreme Court decision, as the inventor of (1) the regenerative feedback circuit, (2) the superheterodyne and (3) wide-band frequency modulation or FM radio. As I reported, Armstrong received and retained the three top medals, specifically for these inventions, from three major scientific and engineering societies.

It may be noted that in the supposedly decisive Supreme Court opinion of 1934, Justice Cardozo used some surprisingly indecisive language in referring to de Forest's claims to the regenerative circuit. These claims rested finally on an old laboratory notebook observation, "which," Cardozo wrote, "means, or was understood, we are told, by de Forest to mean regeneration."

Armstrong never lost his superheterodyne patent. He sold it outright, along with his feedback circuit, to Westinghouse in 1920 for some $400,000. Shortly thereafter, both of the Armstrong patents, as well as de Forest's and Levy's, were swallowed up in the big patent pool designed to bring peace and order to the radio, telephone and electronic industries.

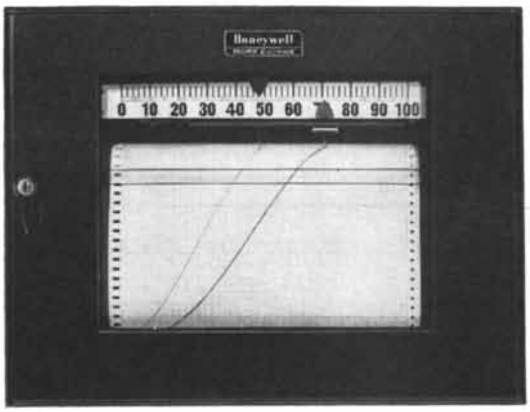
As de Forest is well aware, corporations have been known to seek out patents with parallel or roughly similar claims to those held by others, in order to get a bargaining position or to play one inventor off against another. All this to the end that the inventor be "kept in his place" and not get too "troublesome." Armstrong could never resist fighting back. For this he may well have appeared ever truculent and resentful to some. To others, however, he was invariably courteous, patient, learned and even philosophical.

At this late date it ill becomes the inventor of the radio tube, who has had many hard battles and belated honors of his own, to gibe at the professional and personal misfortunes of his fellow, who has died of them.

LAWRENCE P. LESSING

Upper Black Eddy, Pa.

Automatically plots two variables as a function of a third---



the *ElectroniK* Duplex Function Plotter

NEWEST of the many modifications of the *ElectroniK* recorder, especially designed for research work, is the Duplex Function Plotter. A two-pen version of the now famous Function Plotter, this instrument has three independent measuring systems; one for each of the horizontally moving pens, and one coupled to the vertically moving chart. The instrument is thus able to draw two simultaneous, continuous curves representing the relationship x, x′ = f (y).

In the testing of missiles, engines, nuclear reactions and numerous other studies, the Duplex Function Plotter further helps to accelerate the pace of research. It provides better data by giving scientists a continuous plot of related functions on a single chart, without need for replotting from two separate records. It helps to lift even more of the burden of routine transcribing and data-taking from the shoulders of trained men . . . and frees them for more complete utilization of their skills.

Input to either pen or to the y-axis can be practically any variable that can be converted to a d-c signal. All three inputs can be of different calibrations.

Your local Honeywell sales engineer will welcome the opportunity to discuss your specific applications for this time-saving instrument. Call him today . . . he's as near as your phone.

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● **REFERENCE DATA:** Write for new Data Sheet No. 10.0-17, "*ElectroniK* Duplex Function Plotter."

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MINNEAPOLIS **Honeywell**

BROWN INSTRUMENTS

First in Controls

Look What's Happening in Metals

THE TARRYTOWN STORY: new

TOWN PERMITS NEW USE OF COPPER. Here George F. Ellis tells Town Trustees about proposed new building code for Tarrytown, N. Y., to replace their 1929 ordinances. The Board adopted the New York State "model" Building Code—the 100th community to do so. Today Tarrytowners may build to 1954 standards—not 1929's. They may take advantage of *copper* for home drainage systems.

materials for new homes

THE TOWN FATHERS REPLACED A SET OF BUILDING RULES THAT WERE 25 YEARS OLD. NOW BUILDERS MAY USE MANY OF THE NEW MATERIALS MADE BY COMPANIES LIKE ANACONDA.

The story starts with George F. Ellis. Last year he headed a special citizens' committee in Tarrytown, N. Y., appointed by Mayor Edward N. Vetrano.

The committee's job: to look into a building code that had been law since 1929.

Under this old code, for instance, Tarrytowners couldn't drain their bathtubs through *copper* piping. When the code had been written 25 years before, lightweight copper piping for this use was unknown.

This year George Ellis's committee and the town fathers adopted the up-to-date New York State Building Code.

Now Tarrytowners can have soil, waste and vent lines—as well as water and heating lines—in rustproof copper.

Local codes that take full advantage of copper and other new materials are the trend all over the U. S.

WHY COPPER DRAINAGE SYSTEMS?

Owners like copper drainage systems. They are trim and compact; save on carpentry. In basements where piping is exposed, copper looks neat. It costs less to install. And copper won't rust —*ever!*

Plumbers find copper easy to work with. Because connections are soldered, they don't need heavy tools; don't have to thread pipes or lead joints, and copper piping goes into place easily because it's so light.

NEW METHODS . . . NEW MATERIALS

Under new codes like Tarrytown's, this and many other new materials and methods may be used in today's easier-to-live-in homes.

You can simplify the design of walls and partitions that don't bear direct loads (that saves material); you can use more glass (your house will be brighter); and you can use the newer, more reliable types of electric wires.

All this—rustproof copper drainage systems and much more—gives Americans a far wider choice in the way they may build their new homes.

54276

LIGHT AS A FEATHER? Not quite —but this rustproof copper piping weighs ¼th as much as conventional piping used to drain tubs, lavatories and toilets. It's made by The American Brass Company, an Anaconda subsidiary, and saves plumbers time and homeowners money. More and more towns permit this cost-saving use of copper.

ANACONDA®

PRODUCERS OF: Copper, zinc, lead, silver, gold, platinum, cadmium, vanadium, selenium, uranium oxide, manganese ore, ferromanganese, and superphosphate.

MANUFACTURERS OF: Electrical wires and cables, copper, brass, bronze and other copper alloys in such forms as sheet, plate, tube, pipe, rod, wire, forgings, stampings, extrusions, flexible metal hose and tubing.

"ANACONDA" IS A REGISTERED TRADEMARK

WILL YOUR NEW HOUSE BE ADEQUATELY WIRED? Most building codes mainly cover safety requirements. Safe wiring may still be far from adequate. Best advice: wire ahead, years ahead! For every home use—all the way from pole to meter to appliance—Anaconda Wire & Cable Co. offers your electrical contractor a modern wire or cable to do the job.

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

JULY, 1904: "J. J. Thomson discusses the magnetic field due to a number of negative electrons situated at equal intervals round the circumference of a circle, and rotating in one plane with uniform velocity round its center. The discussion is intended to elucidate the theory that the atoms of the chemical elements are built up of large numbers of electrons revolving round the center of a sphere filled with uniform positive electrification."

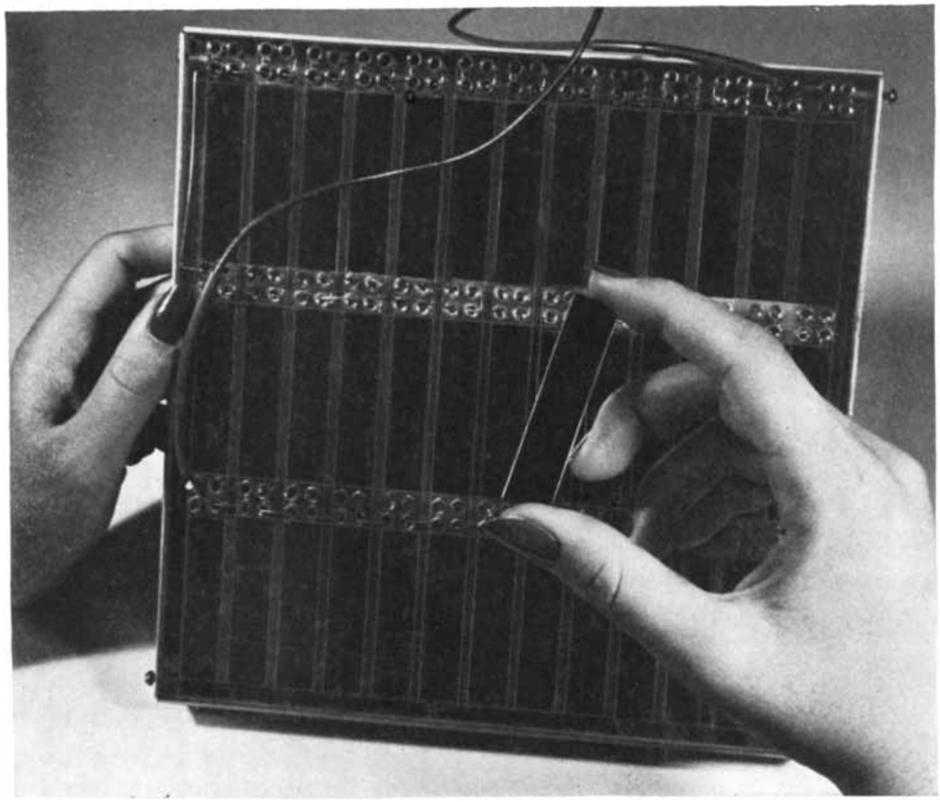
"The two Magellanic Clouds have long been objects of careful study. They have not, however, heretofore been known as regions in which variable stars are numerous. The discovery of a large number of variable stars in the Small Magellanic Cloud led to an examination of the Large Cloud by Miss Leavitt of the Harvard College Observatory. Over 100 variable stars have thus been found. Twenty-one plates, taken with the Bruce 24-inch telescope and having exposures of from one to five hours, were used. A series of six of these, taken within 10 days of each other, has made it possible to derive some inferences as to the periods."

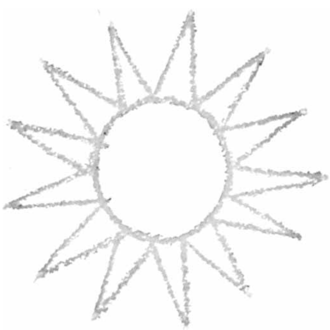
"Dr. W. C. Gorgas, Assistant Surgeon General of the Army, has just returned from a survey of the health conditions in Panama where work on the Isthmian Canal is shortly to begin. Of his plans to control malaria by destroying mosquitoes he writes: 'This scheme was put into effect on a large scale at Havana and, though entirely directed against yellow fever, was almost equally successful against malaria. The same measures that destroyed *Stegomyia*, the yellow fever mosquito, destroyed *Anopheles*, the malarial mosquito. In a small Panamanian village the mosquito work could, of course, be made very much more effective than in a large city of 300,000 inhabitants, and I am very confident that in the course of two or three years mosquito work alone would eliminate malaria in such a village. We must, however, attain our results within a year. I recently heard an engineer, who had been on the ground for some time and was a man of considerable experience, quoted as saying that both the engineering and sanitary problems were simple and could be easily solved. Of the engineering problems I am no judge, but such statements with regard to the sanitary problems, by men of position and experience, I think are very rash and tend to do harm. In my opinion, the sanitary problems are grave. The question of eliminating yellow fever from an endemic focus has been only once before successfully managed, and that was at Havana. And, from this successful work, to argue that it is easy and simple, I think is not warranted. Personally, I believe it can be done, and I approach the work with great hope of success, but I know that it will be neither easy nor simple, that we will meet with many disappointments and have to modify our plans many times.'"

"Messrs. Urbani and Lacombe have separated the new element europium in sufficient quantity to determine the atomic weight. They used 610 grammes of oxides which represented the portion containing europium, coming from the treatment of one ton or more of monazite sands. The europium was separated by a series of fractional operations which required 3,000 crystallizations in all. The atomic weight of europium has been calculated very closely by three different methods and the results are almost identical, fixing the atomic weight at 151.79, within a small percentage."

"It is now 33 years since the question arose at Yale University as to whether or not a baseball thrown from the hand could be made to deviate horizontally from a straight line. The experiment was then and there tried, proving that the flight of a ball could be made to curve to the right or to the left by skillful pitching. This was accomplished by the simple expedient of placing a plank upright on the ground and, from a point at right angles to the middle of one of its broad sides, twirling a ball to a point back of the center of the plank. Since then, it is accepted as fact by all baseball players that the flight of a ball can also, under fine handling, be made to incurve abnormally downward or upward with reference to its landing place; that is, either in the direction of, or contrary to, the attraction of gravitation. The period mentioned was in the infancy of skilled baseball playing. Since then a generation of players of the game has grown up, and the constant repetition of the

The Bell Solar Battery. A square yard of the small silicon wafers turns sunshine into 50 watts of electricity. The battery's 6% efficiency approaches that of gasoline and steam engines and will be increased. Theoretically the battery will never wear out. It is still in the early experimental stage.





Bell Solar Battery

Bell Laboratories scientists have created the Bell Solar Battery. It marks a big step forward in converting the sun's energy directly and efficiently into usable amounts of electricity. It is made of highly purified silicon, which comes from sand, one of the commonest materials on earth.

The battery grew out of the same long-range research at Bell Laboratories that created the transistor—a pea-sized amplifier originally made of the semiconductor germanium. Research into semiconductors pointed to silicon as a solar energy converter. Transistor-inspired techniques developed a silicon wafer with unique properties.

The silicon wafers can turn sunlight into electricity to operate low-power mobile telephones, and charge storage batteries in remote places for rural telephone service. These are but two of the many applications foreseen for telephony.

Thus, again fundamental research at Bell Telephone Laboratories paves the way for still better low-cost telephone service.

Inventors of the Bell Solar Battery, left to right, G. L. Pearson, D. M. Chapin and C. S. Fuller — checking silicon wafers on which a layer of boron less than 1/10,000 of an inch thick has been deposited. The boron forms a "p-n junction" in the silicon. Action of light on junction excites current flow.

BELL TELEPHONE LABORATORIES

IMPROVING TELEPHONE SERVICE FOR AMERICA PROVIDES CAREERS FOR CREATIVE MEN IN SCIENTIFIC AND TECHNICAL FIELDS phenomenon mentioned has become so engrafted upon common experience that few persons conversant with the game ever think it needs explanation. The character of the pitch, whatever it may be, seems just as natural to them as that of the slight vertical curve of the ball compounded simply of the forces of its projection and gravitation."

JULY, 1854: "Kerosene is the name applied to a new liquid hydro-carbon recently obtained from bitumen. The discoverer, Dr. Gesner, of Williamsburgh, N. Y., has received letters patent for his new combination of matter, and operations are now in progress by a company in New York for the extensive manufacture of the valuable products of his invention."

"The news has already spread throughout the length and breadth of our land that 54 fatal cases of cholera occurred in one week in New York City. We would state that nearly as many deaths from consumption take place every week in New York, and, from circumstances connected with those fatal cases of cholera, we believe no fears of an epidemic need be entertained."

"The eminent astronomer Herschel has suggested that the sun may be inhabited, and that between its luminous atmosphere and its surface there may be interposed a screen of clouds, whereby its inhabitants may no more suffer from intense heat than those who live in our tropical regions. This may be so, as we all know how much the heat of the sun's rays, in the hottest days of summer, are modified by an interposing cloud or 'a swift passing breeze.'"

"The commissioners of the London *Lancet*, reporting the result of their investigations respecting colored confectionery, express their surprise at the extent to which deadly poisons are daily used by the manufacturers of those articles. One hundred and one samples were analyzed; and of the yellows, 70 contained chromate of lead and Prussian blue, verditer or carbonate of copper, Scheele's green or arsenite of copper. The above colors were variously combined in different cases, three and even four poisons occurring in the same parcel of confectionery."

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K Ca Cr Mn Fe Co Ni Cu Zn
Sr Ag Cd
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C Si Sn Pb
N P As Sb Bi
O S
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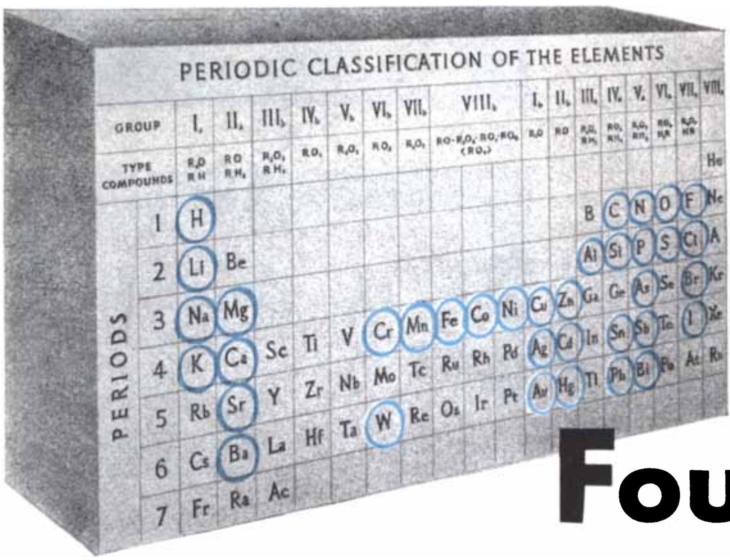

the Foundation

Many factors
are involved in the final quality of a product
in the process industries. The inside story of many difficulties, however,
is often imperfect starting materials — chemicals, for example.
They are the foundation.
Let something go wrong at the beginning and there is often no cure,
no way to avoid trouble, expense and rejections. That's why so many concerns
start with Mallinckrodt chemicals. They're exactly right, always dependable,
and most chemicals you might need are immediately available.
In case they are not now in stock, in case you need special chemicals
to meet specific problems — Mallinckrodt will help you in a hurry
with the right chemical in the right physical form.
An important advantage of a chemical plant like Mallinckrodt's is flexibility
of research and production facilities.

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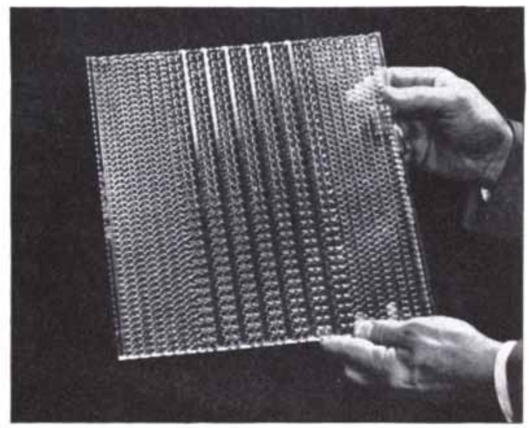
A *TECHNICAL REPORT*
from Du Pont

Properties and uses of Du Pont "Lucite" acrylic resin

Brush backs of "Lucite" are light in weight, warm to the touch, rigid, strong and sparkling-clear.



Lighting fixtures of Du Pont "Lucite" control light to reduce glare. They are easy to clean and are durable.

Automobile dashboards use components of "Lucite" which can pipe light around curves, and glow at the edges. "Lucite" is readily molded into complicated shapes.

"Lucite" acrylic resin combines sparkling clarity with outstanding outdoor stability. "Lucite" may be injection-, compression-, or transfer-molded and extruded to close tolerances in a wide range of transparent, translucent and opaque colors.

Parts made of Du Pont "Lucite" result in saving of weight, and are resistant to shattering. They will resist attack by dilute solutions of strong acids and alkalies, petroleum oils and dilute alcohols.

Lighting-fixture lenses of "Lucite" have excellent light-refracting and transmitting properties. The excellent dimensional and color stability, and light-diffusing properties of translucent "Lucite" compositions give long, efficient service in lighting fixtures. The unique "light-piping" and "edge-lighting" qualities of "Lucite" find use in surgical tools and for decorative applications.

The properties of "Lucite" are listed on the opposite page. Engineers and designers have used these properties to develop many design and product improvements. Several typical applications are pictured here.

Have you and your company evaluated Du Pont "Lucite" in terms of your own product design problems? For additional information on the properties, application and processing of this unique engineering material, mail the coupon today.

ZYTEL†	ALATHON®	LUCITE®	TEFLON®
Nylon Resin	Polyethylene Resin	Acrylic Resin	Tetrafluoroethylene Resin
Tough, Abrasion-Resistant Strong in Thin Sections Form Stability	Excellent Dielectric Properties Tough and Flexible Over a Wide Temperature Range Tasteless, Odorless, Non-Toxic Excellent Water Resistance	Clear, Transparent Outdoor Durability Unlimited Range of Colors Ability to Pipe Light	Heat Resistance Chemical Inertness Dielectric Properties Non-Sticky Characteristics

†*"Zytel" is the new trade-mark for Du Pont Nylon Resin*

DU PONT

REG. U. S. PAT. OFF.

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

TYPICAL PROPERTIES* OF DU PONT "LUCITE"

MECHANICAL:

			METHOD
Tensile strength,	−70°F.	14,500 lb./sq. in.	D638-49T
	73°F.	10,600 lb./sq. in.	D638-49T
	170°F.	5,000 lb./sq. in.	D638-49T
Elongation,	−70°F.	2%	D638-49T
	73°F.	4-9%	D638-49T
	170°F.	80%	D638-49T
Modulus of elasticity,	77°F.	400,000 lb./sq. in.	D638-49T
Shear strength		9,400 lb./sq. in.	D732-46
Impact strength, Izod,	−40°F.	0.30 ft. lb./in.	D256-47T
	73°F.	0.30 ft. lb./in.	D256-47T
Stiffness,	77°F.	430,000 lb./sq. in.	D747-48T
Flexural strength,	73°F.	16,500 lb./sq. in.	D790-49T
Compressive stress at 1% deformation		4,800 lb./sq. in.	D695-49T
Hardness, Rockwell		M98	D785-51

THERMAL:

Flow temperature	304°F.	D569-48
Coefficient of linear thermal expansion per °F.	$4x10^{-5}$	D696-44
Thermal conductivity	1.4 B.T.U./hr./sq. ft./°F./in.	(Cenco-Fitch)
Specific heat	0.35	
Deformation under load, 122°F., 1000 lb./sq. in.	0.7%	D621-48T
Heat-distortion temperature, 264 lb./sq. in.	187°F.	D648-45T
66 lb./sq. in.	208°F.	D648-45T

ELECTRICAL:

			METHOD
Dielectric strength, short-time		400 v/mil	D149-44
step-by-step		355 v/mil	D149-44
Volume resistivity		> 10^{15} ohm-cm.	D257-49T
Dielectric constant,	60 cycles	3.5	D150-47T
	10^3 cycles	3.8	D150-47T
	10^6 cycles	3.3	D150-47T
	60^6 cycles	2.8	D150-47T
Power factor,	60 cycles	0.055	D150-47T
	10^3 cycles	0.040	D150-47T
	10^6 cycles	0.024	D150-47T
	60^6 cycles	0.009	D150-47T

OPTICAL:

Index of refraction	1.49 n_D	D542-42
Luminous transmittance, Illuminant C, ⅛ in.	> 91%	D791-49T
Transmittance at 4500 Å, ⅛ in.	90%	D791-49T
Haze	< 3%	D1003-49T

MISCELLANEOUS:

Water absorption	0.25%	D570-42
Flammability	1.8 in./min.	D635-44
Specific gravity	1.18	D792-48T
Mold shrinkage	0.002-0.006 in./in.	
Compression ratio	1.8-2.2	D392-38

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*Note: This table shows typical property data for Du Pont "Lucite" 140.

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THE AUTHORS

H. H. FINNELL ("The Dust Storms of 1954") was so closely identified with soil conservation measures in the great dust-bowl crisis of the 1930s that he became known as "the watchdog of the southern Great Plains." He is peculiarly fitted to assess the threat of wind erosion rising in that same area today. Born 58 years ago in Mississippi, Finnell spent most of his youth in the Oklahoma Indian Territory. He attended Oklahoma Agricultural and Mechanical College and was an instructor in agronomy before coming to his life's work as pioneer director of the Panhandle Experiment Station. In his 11 years as director he explored soil conservation methods which are still standard practice today. His work brought him into the U. S. Department of Agriculture and, in 1935, when the Soil Conservation Service came into being, he was sent to Amarillo, Tex., to head up the Southern Great Plains Region. After this regional office was closed in 1942, he continued on as a USDA research specialist on wind erosion in all its phases. In 1948 he returned to Oklahoma again to direct the Panhandle Station, while continuing his research for the USDA.

GERARD DE VAUCOULEURS ("The Supergalaxy") is a French astronomer serving at the Commonwealth Observatory in Australia. He has appeared once before on these pages with an article about Mars (SCIENTIFIC AMERICAN; May, 1953). For de Vaucouleurs Mars was only an appropriate wartime avocation, on which he has written one popular and one scholarly book. His chief specialty is the study of extragalactic nebulae, of which the present article is a by-product. Since 1951 de Vaucouleurs has been studying the southern galaxies as a Research Fellow of the Australian National University.

LAWRENCE P. LESSING ("Pure Metals") is a member of the Board of Editors of this magazine.

LINUS PAULING, ROBERT B. COREY and ROGER HAYWARD ("The Structure of Protein Molecules") form an unusual team. Pauling, director of the Gates and Crellin Laboratories at the California Institute of Technology, is one of the world's leading investigators in the structure of crystals and molecules. Born in Portland, Ore., in 1901, he has received many international honors. Corey, who works at the same institution, is an expert in X-ray and electron diffraction studies of proteins and crystals. He was born in Springfield, Mass., in 1897 and came to Cal Tech by way of Cornell University and the Rockefeller Institute for Medical Research. Hayward is best known to this magazine's readers as an illustrator, both of articles and the department "The Amateur Scientist." Scientific illustration is only a sideline with Hayward; he is a practicing architect in Los Angeles. Hayward was born in Keene, N. H., in 1899 and educated at the Massachusetts Institute of Technology.

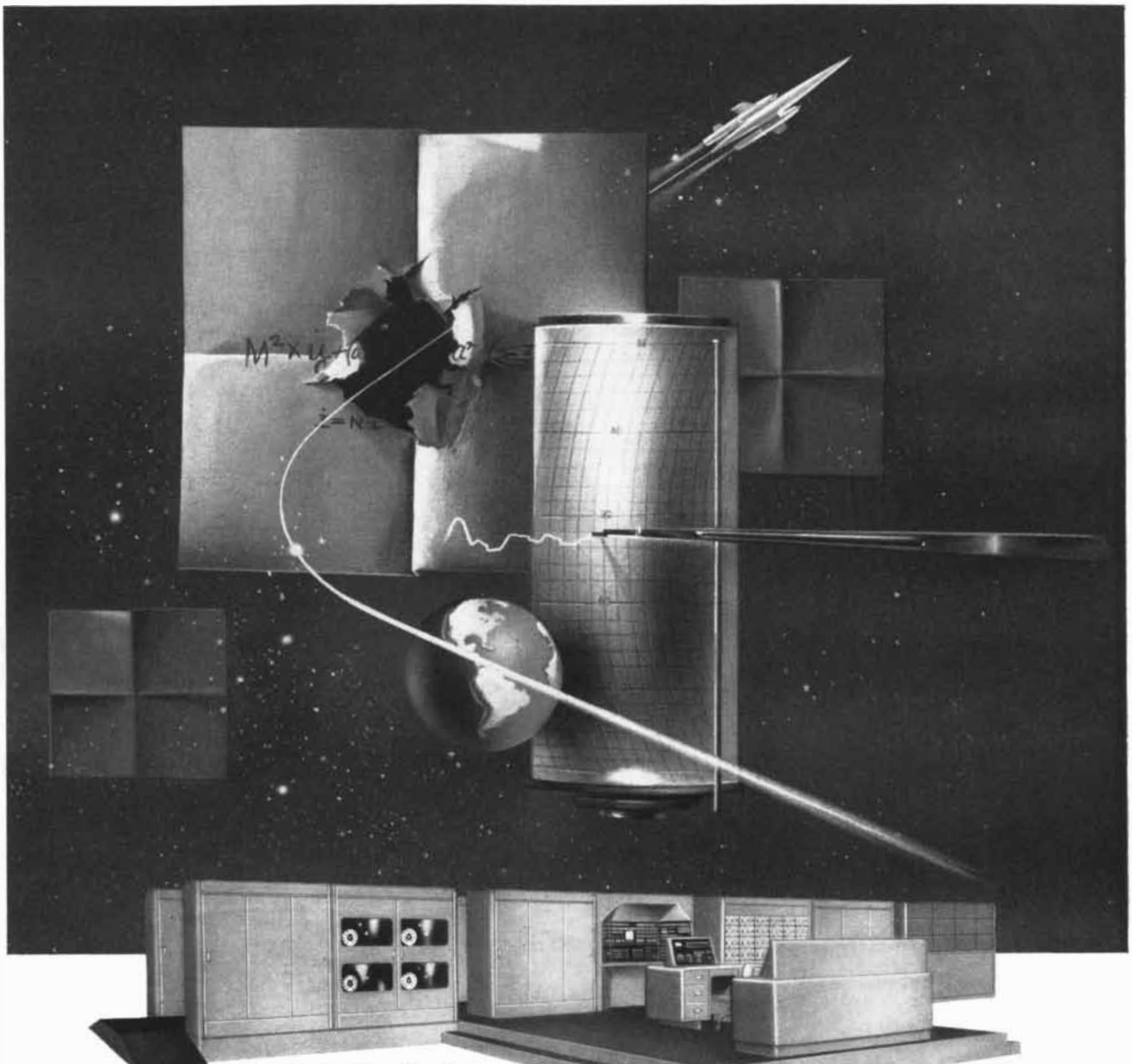
DAVID AND ELIZABETH LACK ("The Home Life of the Swift") are young English ornithologists and husband and wife. He is director of the Edward Grey Institute of Field Ornithology at Oxford University and the author of some notable bird books, including *The Life of the Robin* and *Darwin's Finches*. On the latter subject he contributed an article to the April, 1953, issue of this magazine. The present article bears a double signature because it is in every sense a collaboration. While working together on the investigation of European swift populations, the Lacks were married. This occurred shortly after Mrs. Lack had left wartime service and joined the Institute's research staff in 1946. They shared the long hours of watching a swift colony's family affairs in a college belfry. The Lacks have two sons, and Mrs. Lack has retired temporarily from field work.

JOTHAM JOHNSON ("The Slow Death of a City"), head of the classics department at the Washington Square College of New York University, contributed an article to the May issue of this magazine entitled "The Language of Homer's Heroes." It recounted the breaking of the early Greek or Mycenaean script by a young English architect, Michael Ventris, in one of the notable archaeological feats of this century. Now Johnson writes an account based on his own work at the site of the Roman city of Minturnae. Last year Johnson held a Fulbright research scholarship at the University of Rome.

MITCHELL WILSON ("Joseph Henry") is a novelist, physicist and one-time industrial researcher who has made a name for himself as one of the few literary "regional" writers in the field of science and technology. Born in New

York City in 1913, he felt an equal pull toward literature and science while at New York University and Columbia University. For a time the balance was tipped toward science by a good physics teacher. Wilson did graduate work under I. I. Rabi, became an assistant to Enrico Fermi, doing some early work on the meson, and in 1940 joined the research staff of the Columbian Carbon Company, working on thin films and high-frequency heating. All the while he was also striving to be a writer, selling his first story to *Cosmopolitan* in 1939 and regularly to the "slicks" thereafter, in addition to doing several mystery novels. In 1944 he found he had to make a choice between research and writing. The first product of his commitment to the latter was *Live with Lightning*, a novel which got some critical acclaim as the story of how it is to be a physicist in these times. Since then Wilson has written two novels, *My Brother, My Enemy,* on the tragic life of a pair of American inventors, and *The Lovers*, an interlude laid against the background of Martha's Vineyard, where the author lives. Wilson feels that technology and its men now form the background and hard core of American living, as authentic as the Western plains and mountains of an earlier tradition. He is working on a continuation of his inventors' story, as well as on a history of American science and invention.

ALEXANDER S. WIENER ("Parentage and Blood Groups") is a noted authority on blood groups, both in their medical and medicolegal aspects. He came to his work by a fortuitous conjunction of early interests. While attending high school in Brooklyn, where he was born in 1907, he became interested in mathematics and joined a small group studying differential calculus. At Cornell University he kept up his mathematics through premedical school, and when later he came to do some research on blood groupings at the Jewish Hospital of Brooklyn, he became fascinated by their exactitude and the opportunity for applying his mathematical talents to problems of heredity. There then began a long research career and an early, close association with the late Karl Landsteiner, famous discoverer of blood groups then at the Rockefeller Institute for Medical Research. With Landsteiner in 1937, Wiener was the codiscoverer of the Rh factor. Last year Wiener independently discovered two new blood factors, the U, which is almost universally distributed except among Negroes, and the rare Ca.



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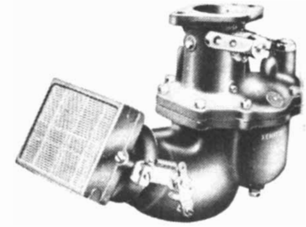

Zenith Carburetor and Flame Arrestor

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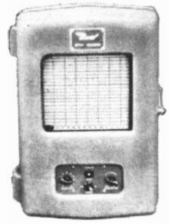

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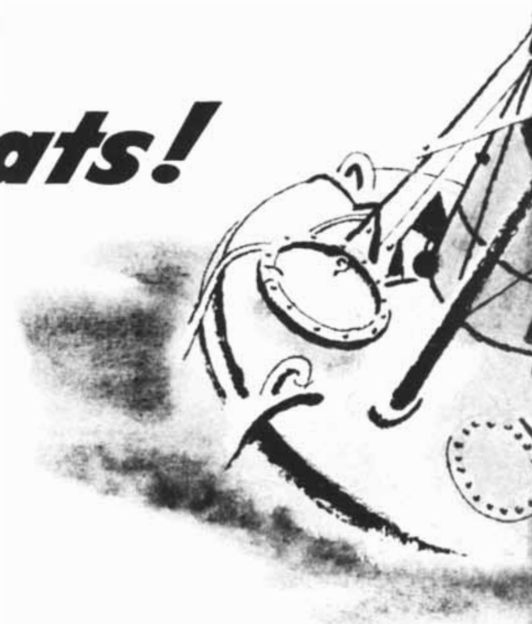

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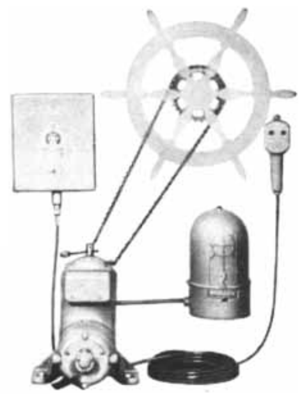
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THE COVER

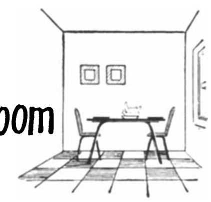
The painting on the cover shows a pair of European swifts in a nest from which the top has been removed (*see page 60*). The swift is the most aerial of all birds: it eats, drinks and mates on the wing. This has certain disadvantages. For example, the male and female birds take turns in warming their eggs and feeding, and on cold or windy days they must spend so much time hunting insects in the air that both are out of the nest at the same time. This leaves the eggs to cool, an emergency to which the eggs of the swift are adapted by evolution.

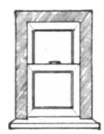
THE ILLUSTRATIONS

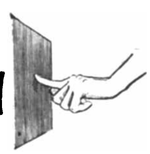
Cover painting by Rudolph Freund

Page	Source
25-26	Soil Conservation Service, U. S. Department of Agriculture
27	Bunji Tagawa
28-29	Soil Conservation Service
31	Mount Wilson and Palomar Observatories
32-35	Bunji Tagawa
37	General Electric Company
38	Paul Weller
39	Westinghouse Electric Corporation
40	John Tremblay
52-53	Roger Hayward (*top*); Gates and Crellin Laboratories, California Institute of Technology (*bottom*)
54-56	Roger Hayward
57	Roger Hayward (*top*); C. H. Bamford, W. E. Hanby and F. Happey (*bottom*)
58-59	Roger Hayward (*left and right*); Robley C. Williams and Mortimer P. Starr, University of California (*center*)
60-64	E. Weitnauer
66-68	Jotham Johnson
72	Frederick Hill Meserve
78	Bernard Hoffman
79	Bunji Tagawa
94-96	Roger Hayward

Who's Who in the growing story of the new vinyl acetate water-based paints

This is a story of a man,  and his wife  and their breakfast room 

They painted it.  Used a brush  and a roller.  Just one coat.  No need to open windows  no "paint" odor. Cleaned brush and roller under tap.  Wiped paint spots off floor  with wet cloth.

One hour later walls were dry  ...and they are washable! 

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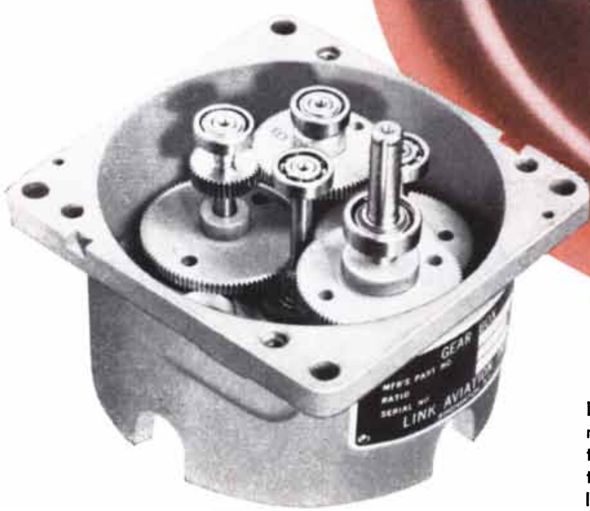

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CONTENTS FOR JULY, 1954 VOL. 191, NO. 1

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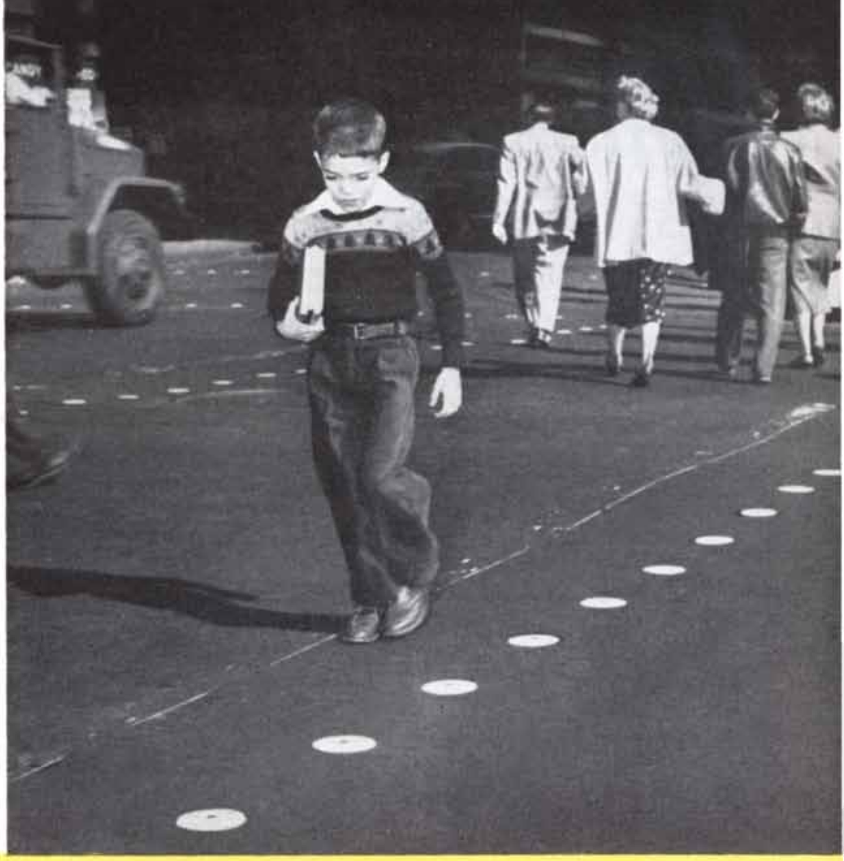

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SCIENTIFIC AMERICAN
JULY, 1954 VOL. 191, NO. 1

The Dust Storms of 1954

As the drifts form and the air darkens on the southern Great Plains, once more the question arises as to what causes these periodic catastrophes and what can be done to forestall them

by H. H. Finnell

In 1954 we have two dust bowls to shame us instead of one. The marginal soils of the southwestern plains, brought under the plow during the wartime agricultural boom, are now well on the way to complete breakdown. Sand drifts have already derailed at least one train; clouds of dust, blowing across highways and obscuring the vision of motorists, have caused serious automobile accidents. The threat that was recognized six years ago [see "The Dust Storms of 1948, by H. H. Finnell; SCIENTIFIC AMERICAN, August, 1948] has all too fully materialized.

It is easy to blame this distressing situation on drought, but that is not the real explanation. Drought is a normal feature of climate on the southern Great Plains. The blame falls not on the elements, but on our refusal to adapt to them. Each wall of storm dust that traverses the plains on the lift of a weather front accuses us afresh of this monstrous failure.

The first full-fledged dust bowl to appear after the lull of the 1940s developed on the loose sands south and west of Lubbock, Tex. Close on its heels came a dramatically sudden outbreak on the

FARM near Johnson, Kan., is bare of crops and crop residues as far as the eye can see. These fields were ruined during one 24-hour period in February. The dust piled along the fence in the foreground is from a similar field across a road behind the camera.

RAILROAD TRACKS on the border of Terry and Yoakum counties in West Texas were cleared of drifting soil before this photograph was made. Telephone poles are half buried.

hard, shallow soils of southeastern Colorado. The annual count of dust storms at the intermediate point of Panhandle Agricultural and Mechanical College in Goodwell, Okla., shows what has been happening. Until 1950 there were about six storms per year, all comparatively mild. Two out of three came from the west Texas area. After that both the total number and the proportion coming from the northwest increased. In 1952 six out of 11 dust storms came from the northwest; in 1953, 17 out of 41. This year 21 out of 29 had blown in from the Colorado area by the end of May.

Both the west Texas and Colorado outbreaks have closely followed the pattern of the original dust bowl in the 1930s, not as to the geographical area affected but as to the sequence of events and the kinds of land involved. For two or three years the crops on lands of marginal fertility had failed. On the unprotected fields the exposed soil moved out with each wind of sufficient velocity to cause erosion. Then these areas expanded and coalesced into the two new dust bowls. They are at present separated by a fairly well-stabilized area which was a part of the old dust bowl.

At this point we cannot guess whether the drought of the 1950s will last as long as that of the 1930s. We do know, however, that it will take at least a year to grow an effective cover crop on the acreage of bare soil now exposed in the twin dust bowls. To this period must be added the time required to sell the idea of planting cover crops to the owners and operators of marginal farms.

So, under the best of circumstances, there are several dusty years ahead. Before they are over, we may at last be able to prove whether the more drastic measures that soil conservationists have been recommending can solve the problem. In brief these measures are: permanently returning to grass the submarginal land now being cultivated, and reducing the amount of time that marginal land lies under cultivation. The latter should be done by increasing both the frequency and the length of the periods during which the land is devoted to grass. Neither of these recommendations has been widely followed in the new dust bowl area. Consequently we do not have a large-scale test of how effective they might have been in heading off the trouble.

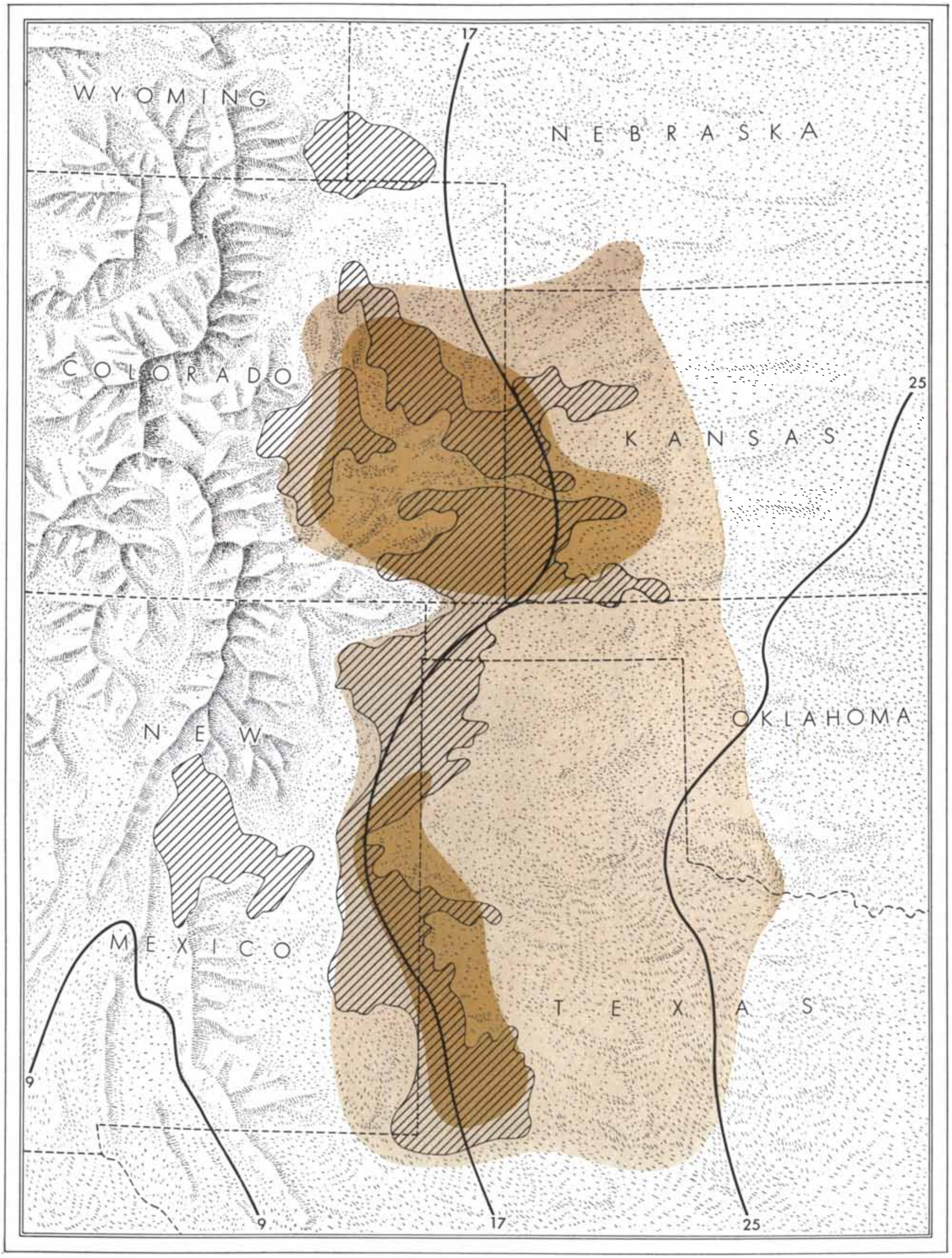
But in the middle of the ravaged Colorado fields stands a remarkable and convincing example of what might be accomplished. This is a tract of about two square miles through which a main line of the Santa Fe Railroad was rerouted 15 years ago to make room for a reservoir. The land was originally a sandy waste of shifting dunes. To make it safe for high-speed rail traffic it had to be covered with permanent vegetation. Clifton Etter, a technician from the Soil Conservation Service of the U. S. Department of Agriculture, supervised the job. Using straw mulch and several native species of grass, he succeeded in revegetating the whole area in three years' time. It has remained stable ever since, with only minimum care to protect it against burning and grazing abuses. Thus far in the drought of the 1950s there has been no break in the ground cover of this tract. All around it, former sod land under the plow less than 10 years has become an acute blowing problem. The better-grade land is a public menace, while under proper care the sand dunes are holding fast.

Whether conservation measures could have averted catastrophe over the whole of the new dust bowls we cannot really tell. All we can say is that existing practices have not. These practices are epitomized by the farmer who says, "Yes, I know this kind of land won't last long, but I can't afford to quit now. I've got to get one more crop out of it if I can."

As long as he stays solvent the average speculator prefers to nourish the slim hope of a miraculous pay-off rather than to close the door irrevocably, give up the land to a less profitable though safe use and write off the inflated capitalization that has been lavished on it. Then, when a failing agriculture has been pursued to the bitter end of insolvency, and erosion makes further cultivation impossible, it is not only the owner who suffers but the public economy and the heritage of future generations.

Research workers of the Department of Agriculture and the state experiment stations have now had time to evaluate some of the consequences of the first dust-bowl era. They have investigated typical wind-blown counties in Colorado, Kansas, Oklahoma and Texas, collecting erosion data, crop histories and yield records for about 800 wheat fields. The productive capacity of the land had been drastically reduced. Soils eroded by wind during the 1930s, although cultivated only 30 years, acted like 70-year-old land in 1947. Erosion proved the major villain: it was half again as effective in pulling down productivity as the depletion of the soil by harvested crops.

There are reliable records covering more than 16 million acres of the old dust bowl as they were in the mid-1930s. In 1949 a sample cross section of this land, comprising some two million acres, was resurveyed and its history brought up to date. The study turned up a rather surprising fact: physical land failure was not the principal cause of farm abandon-



DUST-BOWL areas of 1954 which have been severely stricken are indicated on the map by the darkest color. Areas slightly affected are indicated by the paler tone. The crosshatched areas represent those critical regions of marginal fertility which tend to become dust bowls when they are too long under cultivation. The black contours and numerals show the average annual rainfall in inches.

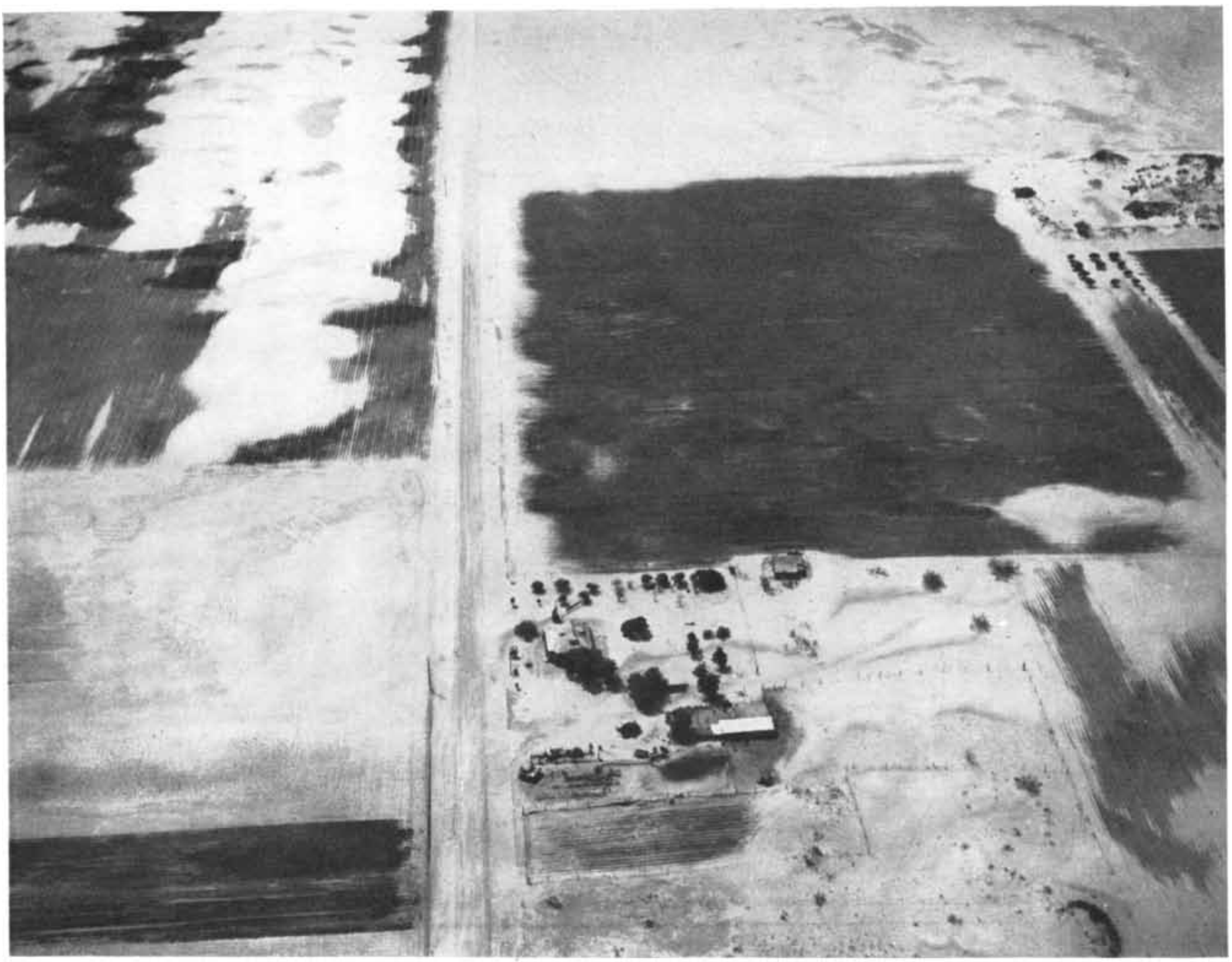
ment. More people fled the plains because of panic and financial distress than because of severe wind damage to the soil. Those who came back had little trouble reclaiming such lands and getting them back into production for the war market of the 1940s.

But there was other land, hundreds of thousands of acres of it, which was abandoned because wind erosion had made it unproductive. Most of it—and this is perhaps the most significant fact to emerge from the study—was poor land from the time it was first placed in cultivation.

Here, of course, is the crux of the problem. How can soils that are suited for cultivation be clearly distinguished from those which are not? The chief disagreement between soil technicians and those who oppose conservation has always revolved around this point. To help in making the distinction the Department of Agriculture has adopted a new system of classifying land, based on the amount of care needed to keep it producing. Class I land is defined as soil that can be farmed without any special provisions to hold it against washing or blowing. Class II land needs simple care to save it from erosion. Class III land is harder to farm: a rather elaborate program is necessary to keep it stationary and productive. Between seasons it should always be covered with a mulch of stalks and straw, held by the stubble from the last crop, and all crop residue should later be plowed back into the soil. Class IV land is on the borderline between soil that can be regularly cultivated and soil that should never be plowed. It needs extremely careful handling if used for crops and should be rested periodically under sod.

The class into which a particular piece of land falls depends on a number of factors. Some of the more important are: the depth of the soil; its constitution—whether hard or sandy; the slope of the land; the amount of rainfall.

The southern plains have been studied to determine how the various types of soils there should be classified and how well each has actually stood up under cultivation. The deep, flat, hard land where most of the wheat is grown was rated Class II since simple care has been enough to keep it from blowing. Less than one acre in 20 of those plowed since farming started on the plains has been seriously damaged or is likely to be abandoned. Deep, flat, moderately sandy land had just as good a record where the average annual rainfall was 18 inches or more, but approximately one acre out of 10 was lost to erosion in the 16- to 18-inch rainfall zone, and one out of four in the 14- to 16-inch zone. Thus it is rated Class II where the rainfall is more than 18 inches and Class III under a rainfall of 16 to 18 inches. With less than 16 inches of rain it cannot be considered arable soil. Flat, hard land of medium depth was worthy of a Class II designation where the rainfall was 18 to 20



WIND EROSION has virtually destroyed this farm, photographed from the air near Brownfield, Tex. Dunes pile up in the field at upper left and around the farm buildings in the foreground. Such land can only be reclaimed by planting it with native grasses.

inches. With less than 18 inches, none of this land stood up well enough for continuous, indefinite cultivation, and it must therefore be assigned to Class IV. The same kind of soil on slopes of 2 to 5 per cent proved to be Class IV anywhere in the southern plains. Sandy lands are never better than Class IV, even though they take up moisture faster than hard lands and allow less runoff to wash the soil away. Sand is very shifty in the wind; it will blow out deeper than hard land when allowed to blow at all. In the sample area 25 to 45 per cent of all sandy land which had been put in cultivation was already abandoned or about to be.

The chief contribution to the blowing clouds of dust comes, of course, from the marginal Class IV soils. Almost invariably this land, once plowed, is kept under cultivation too long. Sometimes a single term of cultivation is enough to ruin it for crops and to reduce its future value even for grazing land.

Even before there was sufficient plowed land close enough together to set off a dust storm on the southern high plains, the hardy individualism of the pioneers provided scattered examples of land failure for settlers to go by. Although the characteristics of grazing land have been recognized longer than those of any other soil, and attempts to farm it have always turned out badly, some people still try it.

In the 1949 land study 259,000 acres of newly plowed land were located and classified. About three fourths of it was Class IV, which cannot be kept permanently in cultivation. The proportion is probably even larger on the arid margins of the plains lying largely to the west. It seems safe to predict, therefore, that not less than three million acres out of the four million that have been plowed since the 1930s have a rugged future cut out for them. Adding these to the older marginal farmlands that have been kept in cultivation largely because of abnormal wartime incentives, we have a grand total of 12 million acres of bare land suffering active erosion as of April 1, 1954, in the five states of the southern Great Plains. This is more acreage than blew at any one time during the worst dust storms of the 1930s.

The southern high plains as a whole have too high a productive potential to be abandoned as a farming region, but those who farm there will have to learn how. Nature will not be outraged with impunity. The people of the region are now talking about conservation legislation. They have done that before. Several states passed conservation laws and tested them successfully in the courts, but, when the pressure of natural emergency eased, so did the public conscience: the laws were repealed and land exploitation was resumed with the vicious result we see today. It is not law, nor incentive payments, nor more scientific information that we need. It is the will to conservation.

CONTOUR PLOWING has checked wind erosion on these fields, photographed from the air near Lubbock, Tex. The land is also protected by other measures. It is plowed in terraces and irrigated. Moreover, the alternate terraces are planted with different crops.

The Supergalaxy

The observations of photographic and radio astronomy indicate that the disk-shaped galaxy of which our sun is an unimportant member is itself a member of a disk-shaped galaxy of galaxies

by Gérard de Vaucouleurs

Man has acquired his knowledge of the universe in much the same way that a child learns about the society of which he is a part. Just as a growing child progressively becomes aware of larger units of human organization—family, neighborhood, city and so on—astronomers have come in the past 400 years to recognize the hierarchical arrangement of the heavens. This astronomical growing-up is still in progress. Until very recently we had the following picture of the universe as a whole: our sun was a member of a galaxy of stars, beyond which other galaxies were scattered without apparent organization. Now we have evidence that our galaxy and those relatively near it form a distinct galaxy of galaxies, what might be called a supergalaxy.

To appreciate the meaning of this discovery we should consider it in the light of man's long struggle to locate himself in the universe. The most tenacious illusion of our ancestors was, as it is of infants, that they were the center of creation. When Copernicus announced in 1543 that a more satisfactory "system of the world" could be built on the hypothesis that the earth moves around the sun, he took the first bold step. But men do not easily surrender their infantile illusions. The announcement touched off a battle which was to rage for two centuries before the new heliocentric view of the world won out. Even then the triumph was incomplete. Astronomers, believing that the egocentric illusions of early man had finally been dispelled, complacently proceeded to develop astronomy on the implicit assumption that our sun occupies a central position in the system of the stars and in the universe at large. This hardy illusion persisted almost to this day, reappearing time and again in new disguises.

By the middle of the 18th century philosophers and astronomers were well aware of the problem of the sun's position among the stars. Emanuel Swedenborg of Sweden, Thomas Wright of England, Immanuel Kant of Germany and Jean Lambert of Alsace all advanced the idea that the Milky Way was a trace on the celestial sphere of the greater system of stars to which our sun belonged. They even carried matters a step further and discussed the possible existence of other stellar systems outside our own, a hypothesis popularized during the 19th century as the theory of island universes. Some, like Lambert, went on to consider a world built up of a hierarchy of systems of ever greater size and content *ad infinitum*. This idea the 19th-century astronomers dismissed on simple mathematical grounds, but some 20th century workers have tried to revive it [see "Modern Cosmology," by George Gamow; SCIENTIFIC AMERICAN, March].

The first real observational attack on the problem was made by the great William Herschel, astronomer to King George III of England. Herschel set out actually to count the stars in different parts of the sky. On the basis of these patient "star gauges" he proposed in 1785 a first crude model of our stellar system. He pictured the galaxy as a flat organization of stars with the sun near the center. This simple picture was later abandoned when Herschel used a larger telescope and found, in places where he thought he had already reached the limits of the system, additional and fainter stars. He then came to think that the galaxy was "unfathomable." His successors during the 19th century contributed little to the problem, and at the turn of the present century the matter had hardly progressed beyond the stage at which Herschel left it.

In 1906 the Dutch astronomer J. C. Kapteyn initiated a new approach which was in fact a modernized version of Herschel's gauges. Kapteyn proposed the celebrated "plan of the selected areas," in which 206 small regions, regularly distributed over the sky, were to be exhaustively investigated at several observatories for star numbers, magnitudes, colors, spectra and so on. He hoped to extract the plan and size of the entire system of stars, which he equated with the universe, from a statistical analysis of the data. Kapteyn published his conclusions in 1922. He put forward a model of the universe rather similar to that advanced by Herschel: a flat disk of stars, some 40,000 light years in diameter, with the sun in the center and the stellar density decreasing in all directions.

This picture, as we now know, is completely false. Kapteyn had been misled by erroneous assumptions regarding the true spread of stellar luminosities, and by the then unknown weakening effect of interstellar matter on the light of distant stars. This tragic failure of a gallant attempt greatly shook the faith of astronomers in stellar statistics alone as a reliable tool to reveal the structure of the universe.

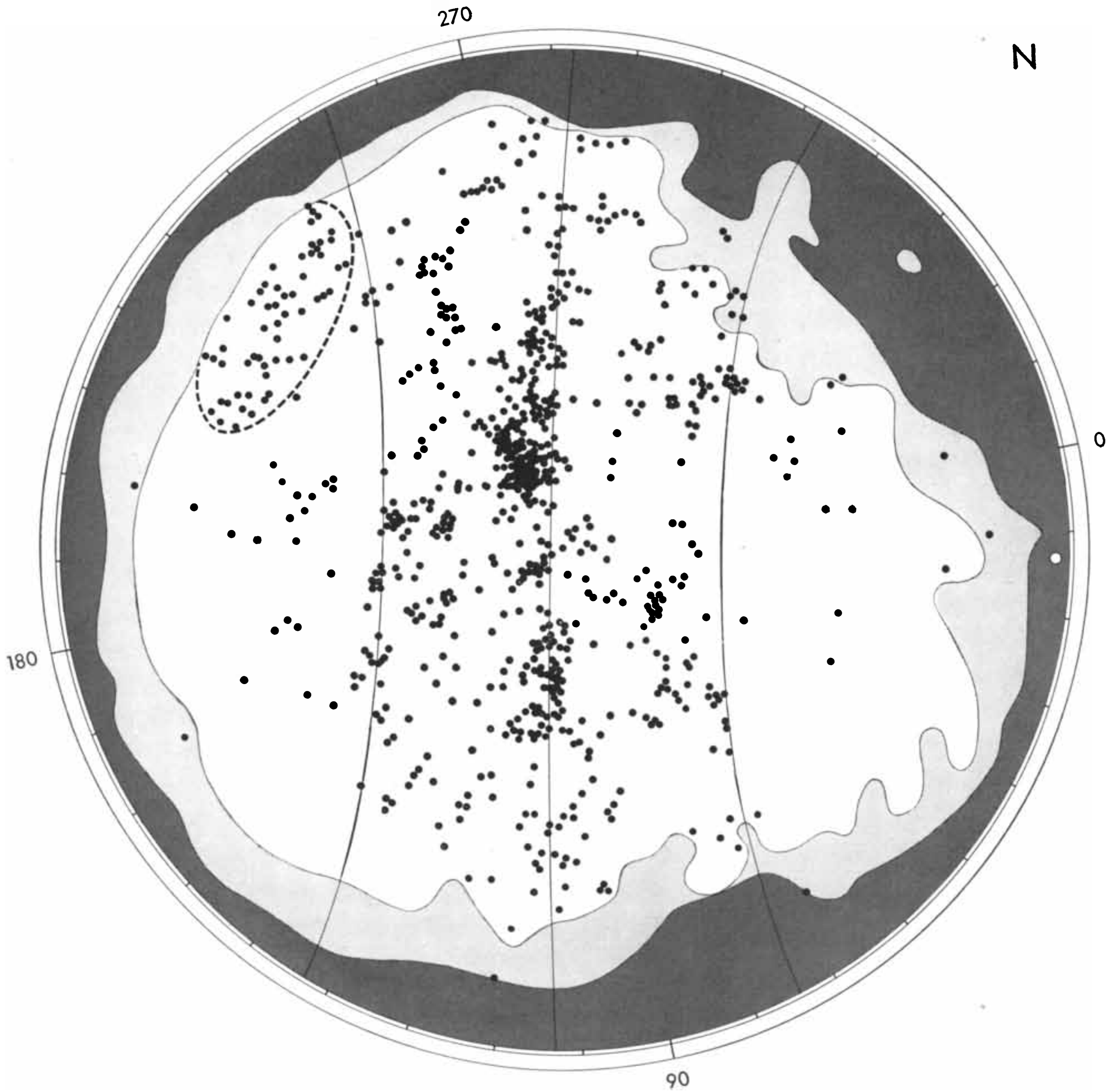
The final solution of the problem (or at least the initial clue which led to it) came from a quite different direction. During the First World War Harlow Shapley, then a young astronomer at the

HUGE CLUSTER OF GALAXIES in Virgo marks the center of the local supergalaxy. The small round objects are mostly stars in our own galaxy. Most of the galaxies have elongated or pinwheel shapes. The entire cluster covers 500 square degrees of the sky. This photograph, made by Fritz Zwicky with the 18-inch Schmidt telescope on Palomar Mountain, covers less than 70 square degrees.

Mount Wilson Observatory, began his famous study of the pulsating Cepheid variable stars in globular clusters [see "A Larger and Older Universe," by George W. Gray; SCIENTIFIC AMERICAN, June, 1953]. Utilizing the relationship between the absolute brightness of these stars and their period of pulsation, he measured the distances of most of the clusters. He found them strongly concentrated toward a common center in the galactic plane well away from the sun, and in 1918 he advanced the audacious hypothesis that the center of the system of clusters is the same as the center of the galactic system. He also suggested that the diameter of the sphere including the clusters, then estimated at 300,000 light-years, gave an indication of the size of the galaxy. When the effect of interstellar absorption was later recognized and allowed for, this estimate was reduced to less than 100,000 light-years. The most important point remained: our sun had finally and irrevocably been displaced from the center of the Milky Way to a point out near its edge.

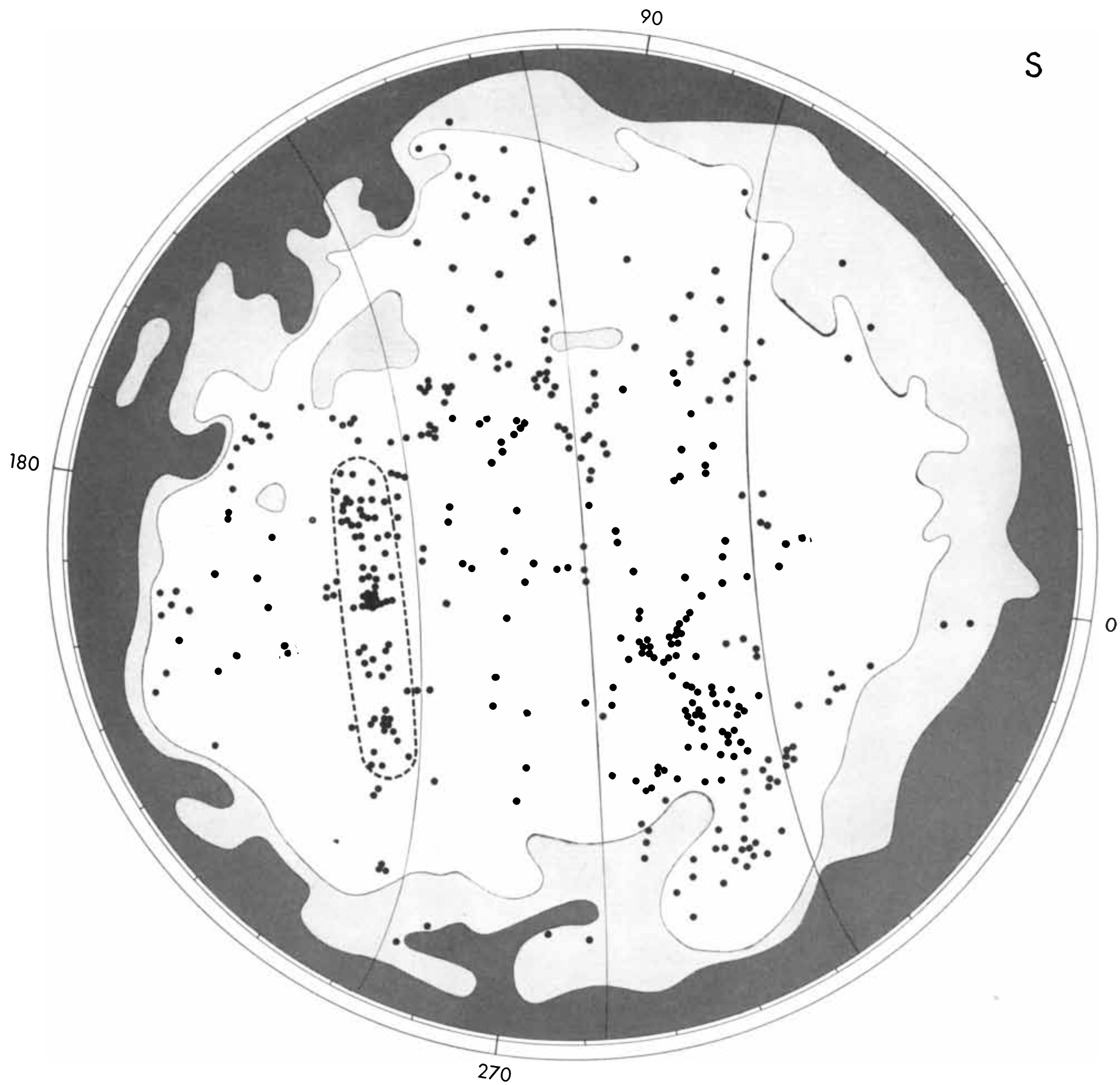
All subsequent progress has substantially confirmed Shapley's picture. In 1927 Bertil Lindblad of Sweden and Jan Oort of the Netherlands showed that the galaxy rotates and that its center of rotation agrees with the center marked by the clusters. Lately the spiral structure of our galaxy has been detected and astronomers are now busy filling in the details.

Once the nature of our stellar system had been elucidated, the debate over the island universes theory could also be



BRIGHT GALAXIES are represented by black dots on these two maps. The map on this page shows the distribution of bright galaxies with respect to the northern hemisphere of our galaxy; the map on the opposite page, the distribution of bright galaxies with respect to the southern hemisphere. The bright galaxies are obviously concentrated along a vertical line, marking the central plane of the local supergalaxy. The equator of our galaxy is around the edge of each map. The darker tone around these edges indicates the settled. Arguments for and against the existence of external galaxies similar to our own had been put forward throughout the 19th century and early years of the 20th. In 1917 G. W. Ritchey of the Mount Wilson Observatory discovered an exploding star or nova in the great spiral nebula in Andromeda. This touched off a chain of investigations which culminated in 1924 when the late Edwin P. Hubble of Mount Wilson succeeded in photographing Cepheid variables in the Andromeda spiral. With this means of estimating the distance of the nebula, it was finally proven to be an outside stellar system.

In the following decade the exploration of the universe beyond the limits of our galaxy proceeded by leaps and bounds until the extreme limit of penetration of the largest telescopes was reached at distances on the order of a billion light-years from our microscopic planet. This exploration was of necessity rather hasty and the picture of the universe which it brought back rather sketchy—a fact of which the observers were well aware, but one which has been widely overlooked by theoretical cosmologists and, in their wake, by popular scientific writers. In order to form a rough, over-all picture of the distribution of galaxies in space, astronomers had to use a sampling technique resembling that of Herschel and Kapteyn. Selected parts of the sky were photographed, galaxies counted and an average or smoothed picture of their distribution derived. The method is sound, but its shortcomings should not be overlooked. From it there emerged in the 1930s a description of the universe



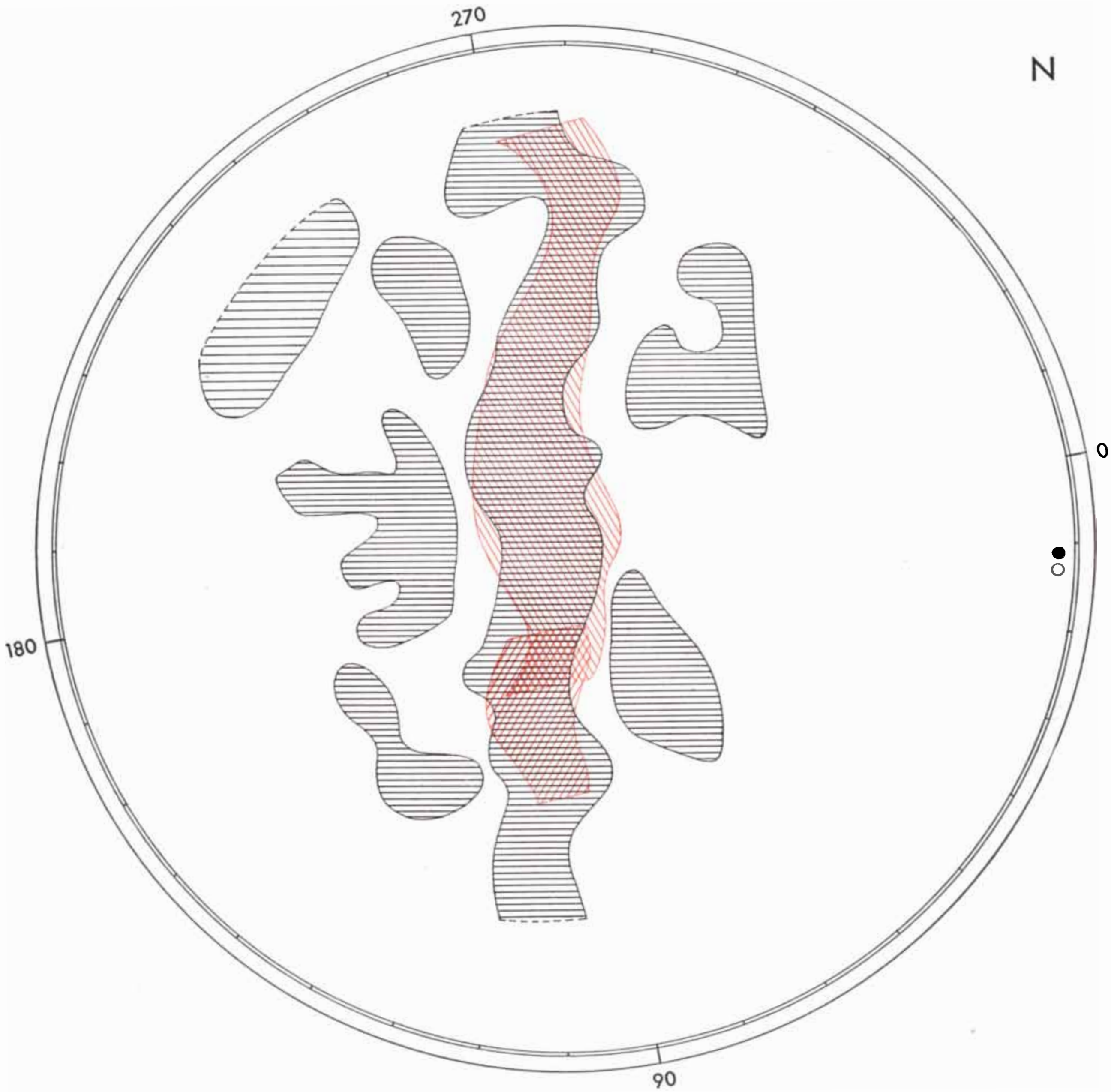
"zone of avoidance," in which external galaxies are blotted out by interstellar matter. The lighter tone indicates the zone of partial obscuration. The densest concentration of galaxies in the northern galactic hemisphere is the Virgo cluster. The dotted line in the northern hemisphere marks the boundary of an external supergalaxy. The dotted line in the southern hemisphere marks the southern external supergalaxy. The small white spot at the right in the northern hemisphere indicates the north pole of the supergalaxy.

in which galaxies are regarded as distributed more or less at random—the so-called "general field," except in a few places where clusters of nebulae appear.

But then other evidence began to come in. Exhaustive explorations of a number of areas in the sky, undertaken by Shapley and his colleagues at the Harvard College Observatory, indicated that galaxies tend in general to form groups and clusters of various sizes. This clustering tendency was later confirmed by Fritz Zwicky at Palomar Mountain and by C. D. Shane and his collaborators at the Lick Observatory. Zwicky has gone so far as to assert that clusters of galaxies are the rule rather than the exception and to suggest that "space . . . may be divided into 'cluster cells' [which] fill the universe just as bubbles fill a volume of suds."

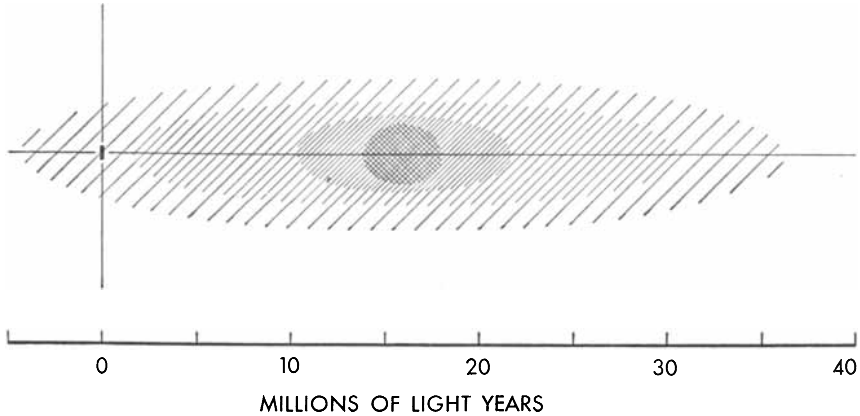
Then arose the problem of determining whether our own galaxy is a member of such a cluster. Indeed, astronomers have known for more than 20 years that our galaxy belongs to a small agglomeration of a dozen or more nebulae, the so-called "local group" which includes the Milky Way, the nearby Magellanic clouds, the Andromeda spiral and its satellites, the spiral in Triangulum and several other nebulae. However, this group was widely assumed to be more or less isolated in the "general field."

Occasional warnings were sounded that the situation might not be so simple. Perhaps the 18th-century philosophers were not so far off the mark in contemplating a hierarchy of systems. In



RADIO-FREQUENCY RADIATION (*colored hatching*) from the central plane of the local supergalaxy closely coincides with the central contour of bright galaxies (*black hatching*) counted on photographic plates of the northern galactic hemisphere. The longer colored section represents radio observations made at the Ohio State University; the shorter colored section, radio observations made at the University of Manchester. The black dot at the far right indicates the northern supergalactic pole as plotted on the basis of radio observations. The open circle just below the dot indicates the pole on the basis of photographic galaxy counts.

1922 the Swedish astronomer C. V. L. Charlier demonstrated how an infinite universe could be built up of such a hierarchy of systems so as to avoid the difficulties raised by the 19th-century mathematicians. He even tried to find evidence in the distribution of catalogued nebulae for a "galaxy of the second order," as he called the supersystem of galaxies. Over the past 20 years other Swedish astronomers, K. Lundmark and his students E. Holmberg and A. Reiz, have made several further attempts with statistical methods, but have reached no definite conclusion.



SCHEMATIC CROSS SECTION of the local supergalaxy shows its strong flattening. The center is toward Virgo. The central plane of our galaxy, shown at the left from the edge and in much exaggerated scale, is at right angles to the central plane of the supergalaxy.

A more direct approach was obviously needed. If the distribution of globular clusters provided the key to the plan of the galactic system, would a simple study of the distribution of bright galaxies show the existence of a supergalactic system? As early as 1923, in fact, the British amateur astronomer J. H. Reynolds had called attention to the singular clustering of bright spirals along a great circle crossing the Milky Way near galactic longitude 100 degrees. The significance of this observation was not clear at the time, when the question of whether spiral nebulae are island universes was still in doubt. Then, in 1932, appeared the Harvard Survey of Bright Galaxies, a list of more than 1,200 of the brightest galaxies in the sky. The map of these objects [*see pages 32 and 33*] strikingly confirms Reynolds' discovery. Why this remarkable distribution failed to attract general attention for so long is a mystery.

Last year the writer published a preliminary statement in *The Astronomical Journal* to call attention to the then available evidence for a "local supergalaxy." This gigantic system of galaxies appears to be a strongly flattened cluster perhaps 40 million light-years across, on the recently revised scale of cosmic distances, and a few million light-years thick. Its uncounted population of galaxies may run into the tens of thousands. Its central nucleus is roughly marked by the well-known cluster of galaxies in Virgo, some 15 million light-years away. Within the local supergalaxy there is much irregularity and sub-clustering as in the case of the "local group."

It is interesting to note that there is no mistaking the outlying position of our galaxy in the supergalaxy. This time there is no danger of falling victim to the old illusion. In fact the Milky Way is so close to the edge of the system that very few nebulae beyond our nearest neighbors appear in the southern hemisphere of the sky. In the northern sky, on the other hand, a rich population of faint galaxies marks the path of the system. This greater richness of galaxies in the northern sky, contradicting the assumed homogeneity of the general field, had puzzled astronomers for many years.

The photographic evidence for the existence of a supergalaxy has recently been confirmed from quite unexpected quarters. J. D. Kraus and his collaborators at Ohio State University and R. Hanbury Brown and C. Hazard at the University of Manchester have been studying the distribution of weak radio waves from the sky outside the equatorial plane of the Milky Way. Late last year both groups announced that they had discovered an extended source of enhanced radiation outside the Milky Way. This region stretches across the northern sky exactly along the path of the most densely populated stratum of the local supergalaxy, *i.e.*, along the supergalactic equator. On the basis of his radio observations Kraus places the north supergalactic pole at a galactic longitude of 13 degrees and a latitude of +5 degrees; the distribution of bright nebulae had placed the pole at the same galactic latitude and a longitude of 15 degrees.

That the supergalaxy should emit radio waves is not really surprising, since it is known that some of the nearest galaxies, and indeed the Milky Way itself, are sources of such radiation. When we know more about the intensity of radio emission from the various types of galaxies it may become possible to estimate the total population of the local supergalaxy without counting nebulae on photographic plates. Or perhaps a comparison of the results by the two methods will give some clues as to whether cosmic radio noise comes from the galaxies or the space between them.

It is reasonable to hope, at any rate, that the recognition of the local supersystem of galaxies will clarify the field of extragalactic research, much as the recognition of the Milky Way stellar system has enabled us to understand the distribution and motion of stars in it. Already some newly discovered facts are beginning to fall into place. In 1951 Mrs. V. Cooper Rubin, then of Cornell University, undertook an original, even unorthodox, investigation of the radial velocities of about 100 bright galaxies. Her results seemed to indicate that the "inner metagalaxy" (the nearest regions of extragalactic space) is rotating. The reported rotation, although not definitely established, may in fact be a property of the local supergalaxy. The strong flattening of the system would seem to indicate that it is rotating. A new survey of the radial velocities of nearly 1,000 galaxies, soon to be published by the Mount Wilson and Palomar Observatories and the Lick Observatory, should provide much additional material for a more detailed investigation of this point, as will a revision of the Harvard photographic survey now nearing completion at the Commonwealth Observatory in Australia.

Several other supergalaxies have been found relatively close to our own: one in Hydra, one in Pavo-Indus and the great edgewise "southern supergalaxy" stretching more than 50 degrees across the southern sky. Nebular counts now in progress at several observatories are revealing more distant systems. Whether these systems form in their turn a still more enormous system of supergalaxies as envisaged in the Lambert-Charlier cosmology is a question for the future.

PURE METALS

When almost all impurities are removed from a metal, it usually exhibits unexpected properties. Many metals are now purified in the search for new materials to meet the demands of technology

by Lawrence P. Lessing

Ever since man first stumbled on nuggets of copper or gold in the bed of some ancient stream, he has been dealing with metals in various degrees of impurity. Even today commercially pure metals contain small but important amounts of foreign elements. So-called pure gold, the buried coin of the realm, is about 0.4 per cent copper and other impurities. Only recently has science or industry begun to approach truly pure metals; *i.e.*, metals in which the impurities have, in some instances, been whittled down to less than one part in 100 million. Since man's history can be written in terms of metals, this foreshadows a new metallurgical age.

The great difficulty, to begin with, was that nearly all metals were found intractably combined with other metals and materials in the earth's crust. For centuries men struggled with fire and crucible to release the more easily separated metals from the ores in which they were hidden. The long Bronze Age gradually gave way to the Iron Age. Then, in the industrial revolution, as iron was rapidly refined on a large scale to steel, and steel was found to acquire a wide range of different properties when alloyed with other metals, more and more difficult metals began to be wrested from their ores. The capture of elusive aluminum and magnesium opened the Light Metals Age.

Beyond these older metals, however, is a range of highly reactive metals, such as titanium, zirconium and hafnium, which are not only difficult to pull from their ores, but, once secured, are the very devil to hold on to. At the temperatures required to melt them, these metals combine furiously with the oxygen and nitrogen of the air and the materials of the vessels containing them to form brittle, spongy masses with no resemblance to metals at all. Indeed, until the last decade they were only theoretical metals. All metals to a greater or lesser degree have the same kind of reactivity, which explains why, under traditional smelting and refining processes, and even with the most advanced techniques, none has yet been secured in an absolutely pure state.

Until a metal is isolated in such purity, its nature and characteristics cannot be fully known. Metallurgy, in fact, is now at a stage that may almost be likened to the prescientific stage of chemistry when the role of pure elements and their combination into molecules were unknown. Large areas in the chemistry of metals remain a mystery. Many physical actions and properties go unexplained. Alloying proceeds by laws not yet entirely known. Though metals literally underpin civilization and constitute more than three fourths of the periodic table of the elements, relatively little in a systematic way has been known about them.

The first impulse to get a pure metal came from the scientific passion for measurement. The atomic weight of silver had to be settled as accurately as possible to provide a key reference in the table of elements. About the turn of the century, after a number of approximations elsewhere, Theodore W. Richards of Harvard University succeeded with great labor in distilling a tiny amount of very pure silver and establishing its weight as the international standard. Later the developments of metallurgical microscopy, the electron microscope and X-ray diffraction plunged research deep into the atomic structure of metals. It was found that a pure metal has a typically tight, crystalline structure in which the atoms are arranged in regular, perfectly spaced polyhedral forms, called a crystal lattice. Alloying materials distort these forms in a regular way, generally adding strength, hardness or other properties to the metal; impurities such as gases, slags or other minerals cause haphazard breaks or discontinuities in the lattice, generally weakening or degrading the metal. From a study of the pure forms, some calculations could be made as to a metal's theoretical strength and other properties, and some of the simplest alloys could be explored.

A few industrial advances were made toward purer metals. Perhaps the most notable was the New Jersey Zinc Company's development in the late 1920s of a fractional distillation process for high-purity zinc, containing less than 0.005 per cent of impurities. This put zinc into the big automobile die-casting market; for the purer metal, unlike ordinary zinc, was corrosion-resistant and made strong, cheap alloys for precision casting. Other metals, such as platinum, were also refined, for special purposes, to fairly high purity on a small scale.

But there was no great impetus toward pure metals until World War II. Then the accumulated knowledge and curiosity regarding metals became linked to the driving demands of three advancing technologies, each revolving on the development of new or old metals to unheard-of purities. Atomic energy required a purity in metals extending from its base metal, uranium, right up to reactors, which had to be made of strange, new, heat-resistant metals that would not absorb too many neutrons, the particles that make an atomic reaction go. Supersonic aircraft required metals able to withstand tremendous heats, a quality that was soon seen to be related to purity or uniformity, for it led to the development of pure titanium, molybdenum and many new high-purity alloys. Finally, new electronic devices, mainly the transistor but including older electronic and microwave tubes, required ultra-pure metals both new and old in order to function at all. Suddenly, there was a greater range of metals closer to purity than ever before.

The first result was the discovery in metals of many remarkable new properties hitherto veiled by impurities. This was not wholly unexpected. Since the earliest production of hard, bright metals from dull, earthy ores, metallurgists have learned to expect large effects from very small, unlikely sources. The reduction of carbon in iron from 4 per cent to about 1 per cent makes all the difference between brittle cast iron and tough steel. Alloys get all their wide range of effects from tiny additions of metals, sometimes in amounts as little as a fraction of 1 per cent. About 0.2 per cent of impurities, mainly oxygen and nitrogen, is all that stands between ductile titanium metal and its nonmetallic forms. The present drive for purity, however, leaves hardly a new or old metal untouched, and the sheer range of new properties is phenomenal.

Chromium, long considered a hard, brittle, almost unworkable metal, used only in plating and in such alloys as stainless steel, is found, in high purity, to be almost as ductile at room temperature as soft wire. Vanadium, another brittle metal used up to now mainly as a toughening agent in tool and spring steels, becomes an unusual ductile metal at high purity.

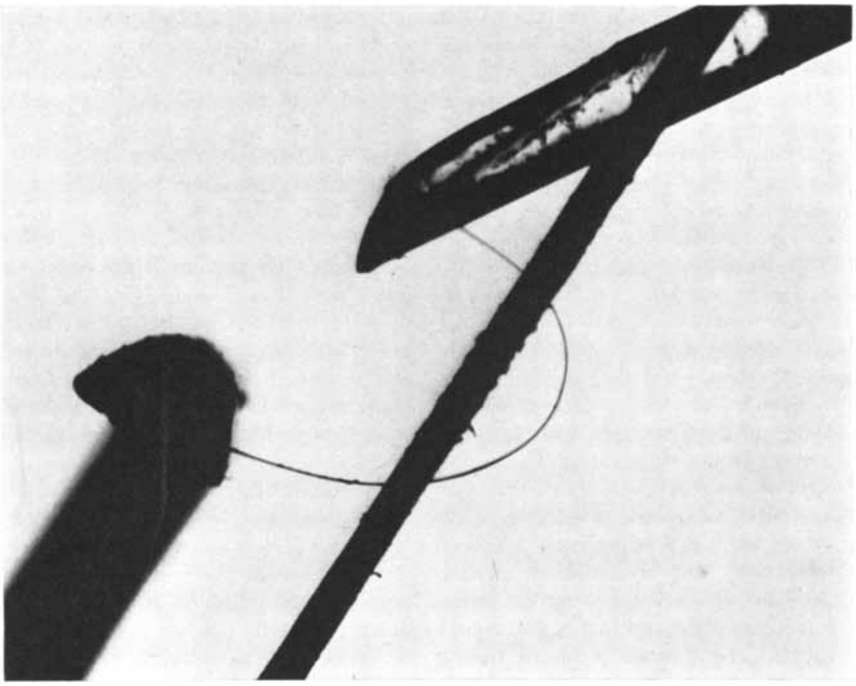
Even more remarkable properties show up in the laboratory. The General Electric Research Laboratory, which has had a broad hand in this field since developing high-purity tungsten for lamp filaments, is growing and studying so-called perfect crystals or microscopic "whiskers" of metals. These were first discovered at the Bell Telephone Laboratories, growing on cadmium. Crystals of iron, grown at General Electric, are about a tenth the diameter of a human hair. Under test they show tremendous flexibility, indicating a tensile strength of almost a million pounds per square inch, close to the theoretical strength of iron and far beyond that of any known metal or alloy. The theory is that in such small dimensions crystal structure is continuous enough to approach the ultimate properties of the pure element.

At the University of Virginia a group under Allan T. Gwathmey has been growing huge single crystals of high-purity metals to facilitate their study in another way. The pencil-thick crystals are sectioned and machined into highly polished slices or spheres, so as to cut through or along one or more faces of the crystal. On a large scale these crystal faces are exactly like those found in the tiny crystal "grains" of the regular metal. Various chemical experiments are then carried out on the prepared crystals and the rates of reaction measured on each of the faces. A dozen metals have thus been studied, including copper, silver, nickel and iron. One face of a copper crystal corrodes about five times faster than another at about 400 degrees Fahrenheit. One face of a nickel crystal promotes a catalytic reaction at least 1,000 times more rapidly than another. Friction and wear also vary from face to face of the same crystal. Thus the different crystal faces of a metal behave as if they were entirely different metals.

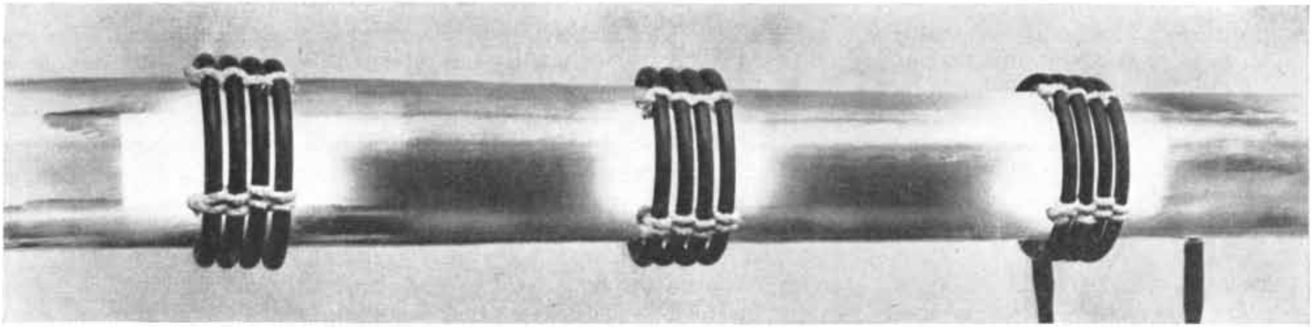
At the same institution another group under Jesse W. Beams has been whirling thin metal films to destruction in the ultracentrifuge and measuring the forces required. The metals are lightly coated on the tiny rotor of a microscopic ultracentrifuge. This rotor, suspended free in a magnetic field, attains tremendous speeds and forces. Again the results are startling. The thinner the metal film, the tougher and stronger it is.

All this would seem to indicate that if we can get metals pure enough, reintroduce small impurities or alloys in a completely controlled way and learn how to orient their surface crystals in a desired pattern, we may unfold an entirely new range of strengths and special properties. So far few of the new discoveries are explainable, much less practical, but the trend is clear. The ferment of research in universities, government agencies and big industrial laboratories is already felt in commerce. A leading supplier of ferroalloy metals like Union Carbide and Carbon Corporation, for instance, has been investigating nearly all its metals in ultra-pure form. Two years ago it brought in two new closed-furnace processes for producing high-purity ferrochrome and manganese to meet the increasingly tight specifications for jet-aircraft alloys.

The problem of producing high-purity metals in industrial quantities is an entirely different proposition from getting them in small laboratory amounts. The first stage is to secure them in as pure a state as possible from their ores. Nearly all the basic ways of doing this are more obviously chemical processes than the old metal-smelting techniques. Titanium and zirconium, which are not metals at all except at high purity, are secured by the Kroll process, named after Wilhelm Kroll, who developed it for the U. S. Bureau of Mines. This is



TINY IRON CRYSTAL grown in the General Electric Research Laboratory has a strength of one million pounds per square inch. The crystal is the tiny loop in the center. The heavy bar running from upper right to lower left is a human hair for purposes of comparison.



ZONE MELTING of germanium is shown here in the type of apparatus in which it was developed at the Bell Telephone Laboratories. Bar of metal is slowly being pulled through a gas-filled quartz tube past induction coils which melt only narrow zones of metal. The molten zones sweep impurities to the end of the bar, leaving behind the highest purity metal yet attained by industry.

a five-step process pivoting upon the reduction of the metal chloride by molten magnesium in an inert atmosphere or vacuum. It produces a sponge metal which must be further processed. Other basic processes range from hydrogen reduction, one of the oldest, to fractional distillation, solvent extraction and the newest ion-exchange methods. Nearly all these processes are in flux as chemists search for more economical or direct means, such as electrolysis, to get purer metals from ores and thus eliminate some of the further laborious process stages.

The crux of present high-purity metals production is the final stages of refining. The effort required to produce a metal 99.9 per cent pure is as nothing to the care and labor needed to remove any part of the last 0.1 per cent of impurities. Anything with less than 0.05 per cent of impurities is an industrial achievement. In industrial terms, chemical purity is not so important as the structural purity or uniformity of a metal's constituents, for most industrial metals are alloys. The developing techniques may be graphically seen in the growing production of zirconium.

This jewel-like metal is closely associated in its ores with 1 to 6 per cent of its sister metal hafnium. They are so closely related that it is most difficult to separate them. Hafnium differs from zirconium in only one important respect: it avidly absorbs neutrons from nuclear reactions. Hence the hafnium had to be got rid of when it was decided to build the atomic submarine reactor (under contract by the Westinghouse Electric Corporation) out of zirconium. Zirconium is not only a low neutron absorber but is lightweight and highly corrosion-resistant. The Bureau of Mines therefore devised an ion-exchange method which, interposed in the Kroll process, acts upon the metals in solution to pull out all the hafnium atoms. (Pure hafnium, thus made available, is a promising new metal in its own right.)

But the zirconium was still not pure enough for reactor purposes. Other slight impurities, which also absorbed neutrons, had to be removed so far as possible. Some years earlier two Dutch investigators, A. E. van Arkel and J. H. deBoer, had devised an ingenious laboratory process for securing ultra-pure samples of titanium, zirconium and other metals. It consists of a glass vacuum still in which a hairpin filament of the metal being sought is heated to well over 1,800 degrees F. The sponge metal, introduced into the still with iodine, forms an iodide vapor which, on contact with the hot filament, deposits crystals of pure metal on the hairpin rods. Westinghouse, finding no more suitable method and no one but itself to do the job, set out in 1950 to adapt the iodide, or crystal-bar, technique to volume production. In 14 weeks it scaled up the process from glass stills to a row of big stainless-steel vacuum tanks, each with clusters of four-foot hairpins. These were soon yielding zirconium in ton lots.

Not long afterwards, however, a more straightforward process was developed by others that produces the metal for less than $15 a pound, against a 1950 price of $250 a pound. Last year high-purity zirconium production was shifted to the new Carborundum Metals Company, using a vacuum method for direct reduction to high-purity sponge metal.

Vacuum methods of one kind or another are the almost universal tool of high-purity metals technology. Nearly all date from only the last four or five years, at least on an industrial scale. Industry generally has been reluctant to work in vacuums, mainly because of their strangeness, but also because they add costs in production time. In dealing with metals, however, in which a very small part of atmospheric oxygen can act as a contaminant, a fairly high vacuum becomes a necessity. Recently other striking advantages have appeared.

Broadly, there are two levels of vacuum used in the new metals techniques. One is embodied in the vacuum arc-furnace, in which a low-vacuum or inert-gas atmosphere is maintained while a large carbon electrode supplies power and heat to the melting metal. This is the tool for primary titanium and zirconium, as well as for high-purity molybdenum, experimentally produced by the Climax Molybdenum Company and under intensive development for advanced jet engines because of its high melting point (4,750 degrees F.). The other level of use is represented by the high-vacuum melting furnace, in which heat is supplied by induction coils around a center crucible and the vacuum maintained is in the region of one 100,000th of an atmosphere. At these pressures, gaseous impurities and other inclusions are literally pumped out of molten metals, while alloying elements may be added with considerable accuracy.

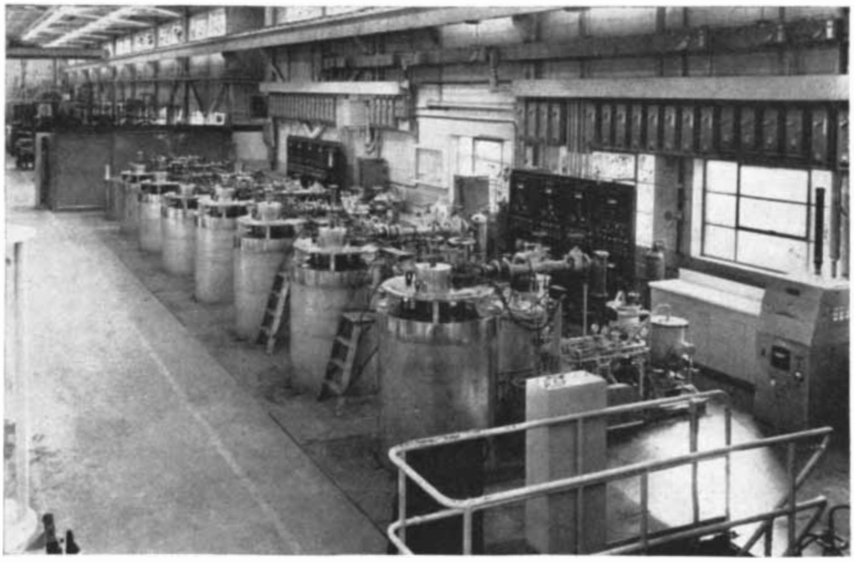
Vacuum metals have had an amazing rise in the past year, mainly through the research of such industrial entities as the Utica Drop Forge & Tool Corporation, General Electric, Westinghouse and two furnace developers, the F. J. Stokes Machine Company and the National Research Corporation. It all started out with the discovery that the vacuum furnace, used to melt uranium in the war program, could melt and conserve high-alloy scrap and, further, could impart improvements in properties to the original complex alloys used for critical jet-engine parts. By this method some special alloys only recently have been shown to have their strength increased by as much as 10 per cent at high temperatures. To get such increments as well as to explore others, nearly all the specialty steel companies and specialists in jet-turbine blades are rushing vacuum-furnace installations. Meanwhile vacuum melting is moving rapidly to other metals for other uses. The theory is that, by drawing out gaseous and other inclusions, a more continuous, cohesive crystal structure is provided for greater strength and other improved qualities. Thus metals for fine-drawn wire are much less subject to breakage after vacuum melting; special bearing steels develop fewer rejects and wear longer, and an experimental automobile-valve spring shows faster recoil for a free increase in horsepower.

Another example of the growth of vacuum melting is the Vacuum Metals Corporation, a 50 per cent interest in which was recently acquired by the Crucible Steel Company of America, with plans for large expansion. Vacuum Metals, a small subsidiary of National Research, built part of its business on the vacuum melting of high-purity copper, iron and nickel. Its copper, for instance, is held to 0.0005 per cent or less of oxygen and nitrogen, 0.0001 per cent or less of sulfur and phosphorus, and similarly small amounts of 13 other trace impurities. Such metals, also made by others, are now widely used for electronic tubes such as magnetrons and klystrons. One manufacturer reports that vacuum metals give such tubes increased performance and a 40 per cent longer shelf life.

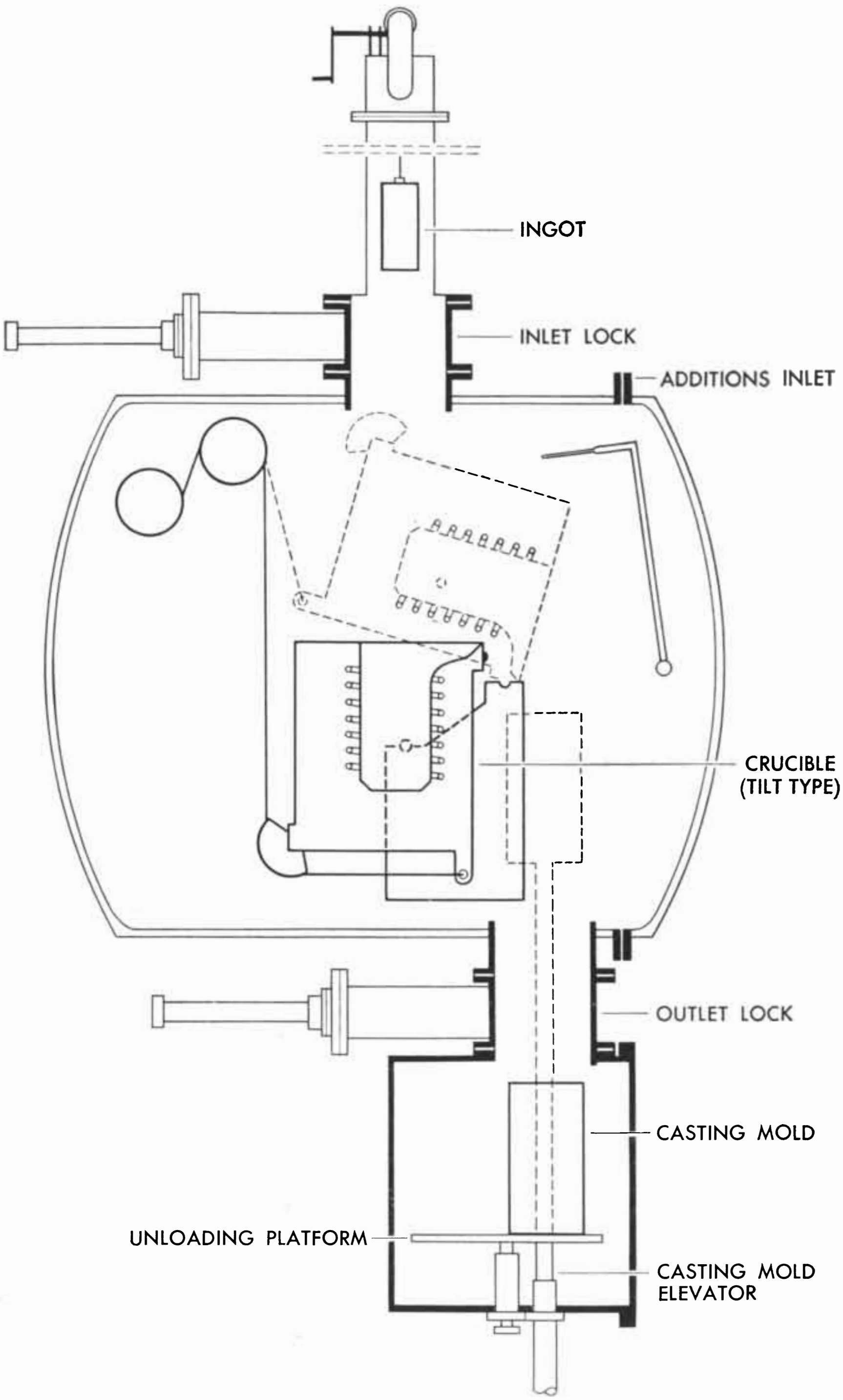
Such purity is nowhere near enough, however, for the metals going into the new electronic transistor devices, invented at the Bell Telephone Laboratories. Bell Laboratories, which has had as basic an interest in metals as any industrial research group, recently announced an entirely new process, developed by W. G. Pfann and K. M. Olsen, that raises the purity of industrial metals to a new frame of reference. By this process, germanium, the semiconducting transistor metal, is refined to a state in which almost no impurities are detectable by present analytical tools; then, by a reversal of the process, a minute impurity (antimony) is reintroduced evenly to the extent of one part in 100 million to make it function as a transistor.

In the process, called zone melting, a long bar of the metal is passed slowly through a series of narrow heating zones, formed by induction coils. Only small portions of the bar are molten at one time. These molten zones travel along the bar and carry with them the impurities, leaving the pure metal to cool and recrystallize behind. As the im-

PURE ZIRCONIUM is deposited by the iodide process on the big hairpin filaments above. The base metal and iodine are heated in a vacuum, in which the filaments are suspended white hot. As the iodide vapor strikes the filaments, it decomposes, depositing the pure metal.



IODIDE PROCESS was taken from the laboratory to this production line of vacuum tanks by the Westinghouse Electric Corporation to get zirconium for the first atomic submarine reactor. Now superseded, it remains an important laboratory process for pure metals.



HIGH-VACUUM FURNACE is rapidly developing as the most widely useful tool for the production of high-purity metals. Ingots, ranging from copper to the latest high-temperature alloys, are charged into the chamber through the inlet lock without losing the vacuum, and are melted in the crucible by induction coils. In the low pressure maintained, gases and other impurities are pumped out of the metal to achieve striking improvements in properties. The molten metal is then cast under vacuum, and removed through the outlet lock.

purities are swept into the last short section of bar, it is cut off and returned for chemical refining. In the reverse process, called zone leveling, a tiny "pill" of the desired impurity or alloy is implanted in one end of the bar and swept evenly through the metal by a single melt zone. Pfann arrived at the process after observing and mathematically analyzing a phenomenon long known to metallurgy: as an ingot or casting of metal cools, its impurities tend to move and segregate toward the top. This fact had been giving transistor men endless trouble as they searched for sections of germanium with the proper uniformity.

Zone melting, which closely controls the solidifying of the metal and the segregation of impurities, is a basically new idea with wide implications. Bell Laboratories is already working it into a number of production forms; it should be possible to use all kinds of heat and even chemical-reaction zones. Bell and others are using it to develop silicon metal for transistors and to explore purity in other metals. Bell hopes to get an answer finally to a question that has bothered it for years: why Chilean copper makes better rectifiers than any other copper in the world. By removing practically all impurities from a metal and then reintroducing them one by one, a new tool is made available for selectively analyzing the nature of primary metals and their alloys.

Still other techniques for handling or getting pure metals are under development. Westinghouse has done much work on levitating or float-melting bits of metal, heated and suspended in a vacuum between electromagnetic induction coils to prevent all contact with furnace walls. Now it is proposed to combine this with zone melting to solve the problem of melting titanium, not yet satisfactorily done, for titanium combines with its container even more rapidly in a vacuum than in air.

The Oak Ridge National Laboratory, interested in exploring new metals for reactor development, has been employing a novel means to get heretofore unavailable rare-earth metals. This is the mass spectrometer or calutron—used in making the original separation of uranium 235—an instrument that literally sorts out minerals atom by atom. By this means the Oak Ridge Laboratory has laboriously secured pound lots of pure cerium, neodymium, samarium and gadolinium.

The physicist is not yet satisfied that he has anywhere achieved an absolutely pure metal, and he will not rest until he has refined metals purer still. It may be that, with the grossness of instruments for analyzing such vanishingly small inclusions in metals, he may never achieve a really pure metal or know that he has achieved it. But the National Bureau of Standards has finally been granted funds for an attack upon this basic problem. About the last thing industry could use would be such impossibly pure metals, for the indication is that they would be too soft for practical purposes. Nevertheless, the striving for purity in metals is already creating a whole new level of industry at the same time that it is expanding our basic knowledge of metals.

Kodak reports to laboratories on:

our latest proposition on cameras... processing line copy of transitory interest... a more sophisticated approach to acids and bases

Bantam RF

Are you in the market for a camera? Here is our latest proposition: $59.75 for the little American beauty pictured above, including the newly lowered Federal Excise Tax. The name is *Kodak Bantam RF Camera*.
1. It takes Kodak 828-size film. That means you get 30% more picture area than with the standard "miniature" camera, and 8 (instead of 20 or 36) exposures.
2. It has a superimposed-image-type rangefinder coupled to the lens.
3. The 50mm *Kodak Ektanon Lens* opens to *f*/3.9 and moves as a unit in focusing from 2½ feet to infinity.
4. The shutter (flash synchronized, of course) can freeze as little as 1/300 second for you. You can't cock it without advancing the film, unless you *want* multiple exposure.

See your Kodak dealer.

No fix

Once upon a time there were some artists in England and on the Continent who thought it took too much time and too much art to do portraits and landscapes the old-fashioned way, so they invented photography. Later it was discovered that photography was not only a fine field for creative artistry but was also very handy for non-artistic tasks like recording oscillograph traces, avoiding tedious penmanship, or reducing a stupendous hardware price list to tidy little cards. Into this workaday world, photography has carried an atavistic preoccupation with permanence. Permanence, reasonably defined, is one of photography's most precious attributes, but where one doesn't really need it there's little point wasting a lot of time and water in its pursuit.

To this end, we draw your attention to a minor chemical invention called "stabilization." It takes the place of the traditional fixation and washing in processing line copy of transitory interest. "Stabilized" images on photographic paper can remain recognizable and legible for some time, but we make no intimations of immortality. The decision to "stabilize" is not an irrevocable death warrant for the image; if, before visible deterioration sets in, the decision turns out to have been rash, one may still fix and wash conventionally before committing it to the archives.

The general idea in stabilization is to convert the undeveloped silver halide into colorless silver complexes which remain in the print. With this may be combined the idea of "hot processing," so that one gives a sheet of photographic paper the works something like this: 1) develop in Kodak Developer PS-451 at 100° F for no more than 10 seconds; 2) squeegee; 3) whisk into Kodak Stop Bath PS-451 at 100° F for two seconds; 4) squeegee again; 5) hold for no more than 10 seconds in Kodak Stabilizer PS-451 warmed to 100° F; 6) squeegee for the last time; 7) dry between blotters.

The rapid sequence and the omission of washing suggest the possibility of a small, portable machine into which one could put, say, a roll of *Kodak Linagraph Paper* exposed to oscillograph traces and read the dry, finished record as it comes out the other end. No mess, yet no sacrifice of the sensitivity of photographic recording. Several manufacturers are now offering such processors, and we shall be happy to send you their names.

To try this stabilization processing, write Eastman Kodak Company, Industrial Photographic Division, Rochester 4, N.Y., for more specific directions, the name of the nearest dealer who sells "PS-451" chemicals, and a little warning about the possibility of staining other papers or clothing by contact with stabilized prints. It would help if you told us what you propose to stabilize.

Beyond pH

The lady (above right) is Dr. Marion Maclean Davis of the Physical Chemistry Section, National Bureau of Standards. Many a practical chemist who got his academic training a couple of decades ago might do well to acquaint himself with what she has been up to since he left the halls of ivy. The result could be a more sophisticated approach to the subject of acids and bases.

Doctor Davis' big contribution has been to chart the shoals in applying water-based concepts of "pH" to the non-aqueous organic liquids that have proliferated in lubricants, transformer oils, motor fuels, dry-cleaning solvents, automotive antifreezes, refrigerants, plastic molding preparations, and other products. For a thorough introduction to Davis, send 20¢ to the Superintendent of Documents, Washington 25, D. C., and ask for Research Paper RP1825. There is much theory in it and much practical working procedure featuring an acidic indicator for use in hydrocarbons—*Tetrabromophenolphthalein Ethyl Ester*.

Unlike familiar indicators, this one does more than simply indicate the passing of a certain pH range by a change in color. It can assume virtually any hue on the color map. Thanks to Doctor Davis and her colleagues, these hues convey considerably more chemical information than just the degree of basicity or acidity.

In the paper mentioned will be found directions for the preparation of Tetrabromophenolphthalein Ethyl Ester. *These you can now conveniently skip. The least we can do to honor Doctor Davis' work is to take the compound out of the "not available commercially" class in which she found it. Eastman 6810 is the number, and $2.50 is the price per gram from Distillation Products Industries, Eastman Organic Chemicals Department, Rochester 3, N. Y. (Division of Eastman Kodak Company).*

Prices include Federal Tax where applicable and are subject to change without notice.

This is one of a series of reports on the many products and services with which the Eastman Kodak Company and its divisions are . . . *serving laboratories everywhere*

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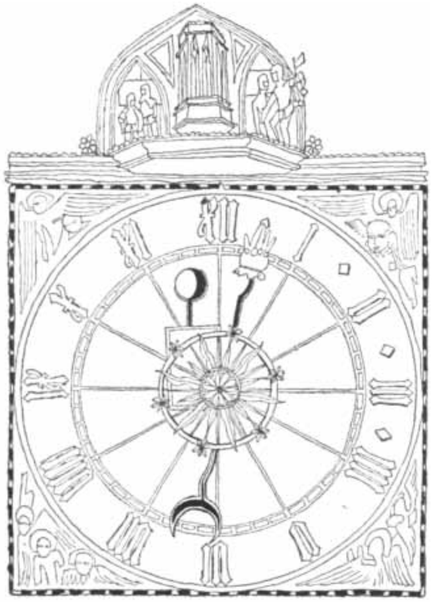
SCIENCE AND



Oppenheimer Decision

Whether J. Robert Oppenheimer is a security risk was still to be decided when this issue of SCIENTIFIC AMERICAN went to press. The question was in the hands of General K. D. Nichols, general manager of the Atomic Energy Commission, and of the commissioners themselves. The Commission's special Personnel Security Board had recommended in a split decision that Oppenheimer's clearance not be restored. Oppenheimer's attorneys asked permission to present an additional brief and oral argument to the AEC itself. Nichols denied the request for oral argument, but said that the brief would get "very careful consideration."

The Security Board's decision came after weeks of hearings during which it had collected 3,000 pages of testimony and examined "the same amount of file material." The panel judged Oppenheimer to be loyal and discreet, with "an unusual ability to keep to himself vital secrets," but it decided by a two-to-one vote that he is a security risk. The majority listed four "controlling considerations": Oppenheimer has shown a serious disregard for the security system; he is susceptible to influence by other people; his conduct in the hydrogen bomb program was "disturbing"; he was not candid in parts of his testimony before the Board. Voting to deny clearance were Gordon Gray, president of the University of North Carolina, and Thomas A. Morgan, former president of the Sperry Corporation. Ward V. Evans, professor of chemistry at Loyola University of Chicago, dissented.

The majority report reviewed the allegations which had been detailed in a letter from K. D. Nichols, general manager of the AEC. It found the charges of old left-wing associations and activities to be substantially true. As to Oppenheimer's role in the development of the hydrogen bomb, the Board decided that he had not actively lobbied against the program, as was alleged, after the Presidential decision to go ahead. Nevertheless, stated the report, "if Dr. Oppenheimer had enthusiastically supported the thermonuclear program . . . the H-bomb project would have been pursued with considerably more vigor." Oppenheimer's claim that he had opposed only the "crash" program was "not entirely candid."

Said the Board: "National security . . . must be absolute and without concessions for reasons of admiration, gratitude, reward, sympathy or charity." Despite evidence of Oppenheimer's "deep devotion to his country" and his "active service in all sorts of Government undertakings," and despite the fact that his past history does not reflect on his loyalty, his actions since 1947 must be judged against the background of that history. The majority found a number of occasions to doubt Oppenheimer's present reliability: He has continued to associate with Communists, current or former, one of whom once tried to get secret information from him. As the result of a "severe attack" by Edward U. Condon, then director of the National Bureau of Standards, he publicly repudiated testimony he had given in private to the House Committee on Un-American Activities. Moreover, he now stands ready to support Condon in the latter's loyalty investigation. He helped to get an academic job for David Bohm, who had declined to testify before the Un-American Activities Committee, and says he would still recommend Bohm as a physicist. In advising on the H-bomb he exercised "influence on matters in which his convictions were not necessarily a reflection of technical judgment, and also not necessarily related to the protection of the strongest offensive military interests of the country."

In considering the question of whether a denial of clearance to Oppenheimer would antagonize scientists, the Board suggested that scientists and intellectuals are "ill-advised" to consider themselves under general attack. "Groups of

THE CITIZEN

scientists have tended toward an almost professional opposition to any inquiry about a member of the group. . . . There have been attitudes so uncompromising . . . that some witnesses have, in our judgment, allowed their convictions to supersede what might reasonably have been their recollections."

In his dissent from the majority opinion Evans said that Oppenheimer had been cleared in 1947 on virtually the same evidence now used to convict him. "They took a chance on him . . . and he continued to do a good job. . . . To deny him clearance now . . . when we must know he is less of a security risk than he was then, seems hardly the procedure to be adopted in a free country." Evans found "absolutely nothing in the testimony" to show that Oppenheimer had hindered the hydrogen-bomb program. The minority member said he was worried over the effect of the decision on the country's scientific development.

Lloyd K. Garrison, Oppenheimer's principal attorney, wrote to General Manager Nichols outlining some of the issues he hoped to present to the AEC. Garrison asked how a scientist can risk advising the Government if "at some later date a security board may weigh . . . the degree of his enthusiasm." To accuse Oppenheimer of giving advice that went beyond bare technical judgment and that stressed defensive as opposed to offensive weapons, Garrison said, is to condemn him for his opinions.

In answer to the charge that Oppenheimer was less than candid, the attorney pointed out that many documents were not given to the defense in advance but were revealed only on cross-examination, causing "the maximum surprise and confusion." He noted Evans' opinion that although Oppenheimer's "statements on cross-examination show him to be still naive," they also show him to be "extremely honest." Garrison requested that as much of the 3,000 pages of "file material" as possible be made available to the defense.

Garrison agreed with the Board's dictum that "a reasonable and sane inquiry" does not constitute a general attack on scientists and intellectuals. But, he continued, "this statements begs the fundamental question as to what are the appropriate limits of a security inquiry under existing statutes and regulations and under a government of laws and not of men—a question of concern not merely to scientists and intellectuals but to all of our people."

Antiproton

The bewildering array of fundamental particles now confronting physicists includes two particularly troublesome types. Some of the particles that have been found cannot be accounted for by present theories; some that the theories predict cannot be found. Now one of the expected-but-not-detected particles appears to have turned up. Bruno Rossi of the Massachusetts Institute of Technology has obtained a "most unusual" cloud-chamber picture which probably shows a trace of the long-sought antiproton.

The history of "anti" particles goes back to 1930, when the English physicist P. A. M. Dirac framed a new theory of the electron. His equations showed that there should be electrons having negative energy (not to be confused with the negative *charge* of the ordinary electron). Dirac suggested that the negative energy particles are undetectable, but that a great sea of them pervades all of space. If one of these particles could gain enough energy to be raised to a positive level, he said, it would appear as an ordinary electron. At the same time, the vacancy left in the negative energy sea would itself act like a particle. This would be an antielectron, or an electron with positive charge. The theory also predicted the reverse process: an ordinary electron could dive into the negative sea to fill a vacancy, thus destroying itself and the antielectron, and releasing the energy which had originally created the vacancy. The whole concept sounded implausible to most physicists and it was accounted a weakness in Dirac's otherwise successful theory.

Then, in 1932, the antielectron was actually found. It was named the positron, and it soon proved to behave according to expectation. To create positron-electron pairs requires the predicted quantity of energy; electrons and positrons "annihilate" each other, releasing energy in the form of gamma rays.

The theoretical arguments which require the positron apply as well to some of the other particles, notably the proton. In other words, there should be negative protons. But much more energy is necessary to produce an antiproton than to make a positron. Presumably the energies now available in the laboratory are not high enough to do the job at all, or do it so infrequently that they have not yet been caught in the act.

The particle in Rossi's picture was produced by a high-energy cosmic ray at the Interuniversity High Altitude Observatory in Colorado. The photograph shows a heavy, low-speed particle coming from a lead plate which caught the cosmic ray. The particle then strikes a brass plate in the chamber. From this second plate emerge three cascades of electrons, such as can only be produced by high-energy gamma rays. The heavy particle was not traveling fast enough to set off any such spectacular reaction. Furthermore, the particle has disappeared. The most straightforward explanation is that the particle was an antiproton which was annihilated together with a proton in the brass.

Unfortunately there was no deflecting magnetic field around the chamber to indicate the charge of the supposed antiproton. Moreover, as Rossi points out, the present state of particle theory does not engender unlimited confidence in interpreting experimental findings. Nevertheless the antiproton seems the best explanation for the mysterious track.

Atomic Energy Legislation

Public hearings on the administration's bill to amend the Atomic Energy Act have revealed such wide divergence of opinion that some observers believe no legislation will be enacted during the present session of Congress.

Industry, which generally favors the measure, has expressed reservations. Some spokesmen have argued that there must be private ownership of fissionable materials, on which the proposed law retains the present Government monopoly. A representative of the General Electric Company called for Government liability insurance against catastrophic nuclear accidents. He said the insurance cannot be obtained from private underwriters.

Public power groups, unions and others have strongly opposed the bill, particularly its patent section, which would allow unrestricted private patents on all nonmilitary applications of atomic energy. Many witnesses told the Joint Committee on Atomic Energy that this would create a patent monopoly, chiefly in favor of big companies which have already had experience in the field as AEC contractors. The President, in his message to Congress earlier this year, had expressed the same fear and recommended a compulsory licensing provision under which inventors would be compelled, for a few years, to license

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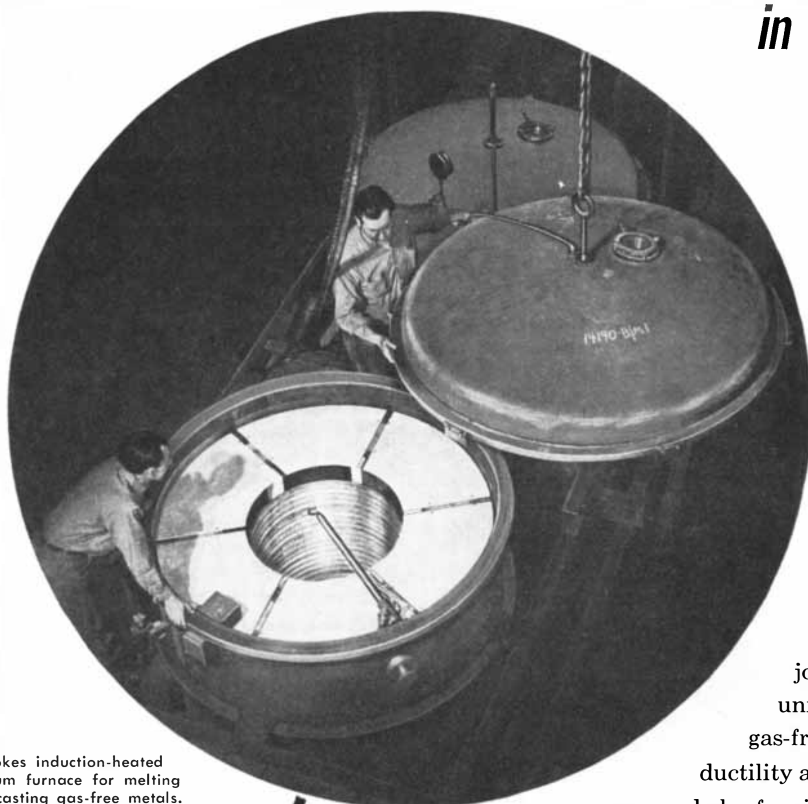

A Stokes induction-heated vacuum furnace for melting and casting gas-free metals. Such metals have extreme purity, high ductility, great impact and rupture strength, improved creep resistance and exceptional performance qualities.

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You can have Stokes vacuum furnaces for top or bottom pouring, for single or multiple ingots, for centrifugal castings. We build tilting type induction-heated melting furnaces of 10 to 1000 pounds capacity; movable retort resistance-heated furnaces for degassing and annealing in 10, 20 and 30-inch retort sizes; resistance-heated furnaces with removable heat source or with bell-type retort; two-zone furnaces with movable boat, and others.

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STOKES MAKES: High Vacuum Equipment, Vacuum Pumps and Gages / Industrial Tabletting, Powder Metal and Plastics Molding Presses / Pharmaceutical Equipment their patents to others. The recommendation was not incorporated in the bill.

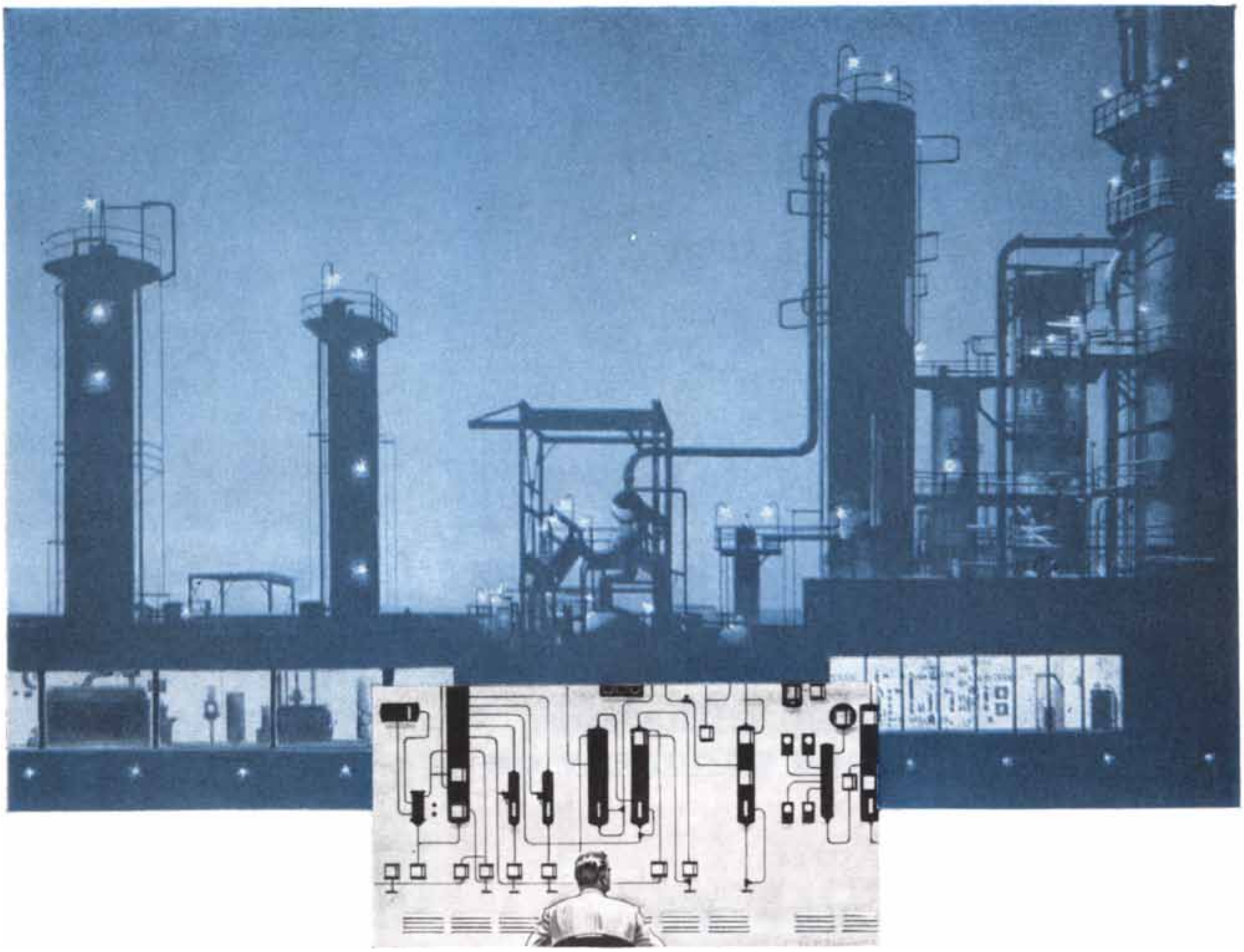
Another controversial issue was the phrase that would make the chairman of the AEC its "principal officer." Strong opposition to this step by Democratic members of the Joint Committee and by three of the five present members of the Commission—Henry D. Smyth, Thomas E. Murray and Eugene M. Zuckert—finally led to a compromise. The disputed section was changed to provide that each commissioner shall have "equal responsibility . . . in all decisions and actions of the Commission," but that the chairman shall be "official spokesman" and, "as agent of the Commission, shall see to the faithful execution of the policies and decisions of the Commission."

New Check on the Ether

When A. A. Michelson and E. W. Morley performed their famous experiment to determine the earth's speed through the ether, they did not actually get the null result on which the theory of relativity is predicated. Comparing the speed of a light beam in the direction of the earth's motion with that of a beam at right angles to the motion, they found a difference, but much less than was expected on classical theory. Physicists generally have agreed that the experiment showed the velocity of light to be constant, within the limits of error in the method, regardless of the motion of the observer. They therefore abandoned the old picture of a stationary sea of ether which carries light and other electromagnetic waves. Nevertheless, many have felt a nagging itch to settle the matter more conclusively.

Now L. Essen, of Britain's National Physical Laboratory, is planning a new measurement using very short radio waves. He will determine the velocity of this radiation by studying its behavior in a cavity resonator—a metal chamber which reinforces microwave oscillations of a particular frequency. The exact resonant frequency of the chamber depends on its dimensions and on the speed with which the waves travel in it. Thus, if the cavity is rotated through 90 degrees, a difference in the velocity of electromagnetic waves for the two directions should show up as a shift in frequency. On classical theory the shift should be about five parts in a billion for a 9,000-megacycle wave.

Writing in *Nature*, Essen says that the frequency of a 9,000-megacycle cavity can be held so nearly constant that it does not change more than one part in a billion per hour. The frequency can be



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checked against a standard to an accuracy of one part in 10 billion. Essen believes that the cavity resonator is at least 10 times as accurate as Michelson's interferometer. Most of the necessary equipment is already available, and the British physicist intends to go ahead with his experiment as soon as "other commitments allow."

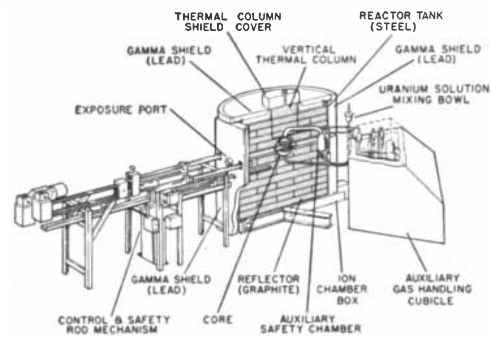
Automatic Gambler

There is now a computer that outwits people at the simple-minded game of matching pennies. Designed by D. W. Hagelbarger of Bell Telephone Laboratories, the humiliating device wins 55 to 60 per cent of the rounds against all human comers. The machine's object is to match its opponent's choice of heads or tails. In playing a round the opponent first records his choice, then pushes a button which causes the machine to choose. The results are compared and the machine is informed whether it has won or lost.

Actually there is no great trick to winning at this game. It has been proved that a random series of choices will beat any other series. But it seems impossible for people to play completely at random, whereas the machine is provided with a built-in table of random numbers to guide it. If the machine detects a "system" in its opponent's game, however, it can do even better. For example, some people who have won twice in a row on one choice tend to switch for the next round. Hagelbarger's automaton notes such tendencies and plays accordingly. Opponents who know of this ability have tried playing in one pattern for a time and then reversing it, but the machine was not fooled.

Claude E. Shannon, Hagelbarger's colleague at Bell Labs, built a second penny matcher along the same lines, but using a different criterion for deciding when the opponent's play pattern justifies a departure from random choices. In an article in the *Proceedings* of the Institute of Radio Engineers, Shannon describes how the designers tried to figure out mathematically which machine could beat the other. They finally had to give up and leave the question to experiment. They built a third machine to act as umpire and go-between, plugged all three together and let them run, "to the accompaniment of small side bets and loud cheering." Although he does not specify the owner of the winning gadget, Shannon reports that the "more precipitate of the two consistently beat the larger, more deliberate one in a ratio of about 55 to 45."

a low cost source of neutrons



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The Structure of Protein Molecules

A protein molecule is composed of thousands of atoms. How are they arranged? Progress has been made toward answering the question for fibrous proteins such as hair, horn, fingernail and porcupine quill

by Linus Pauling, Robert B. Corey and Roger Hayward

The human body is about 65 per cent water, 15 per cent proteins, 15 per cent fatty materials, 5 per cent inorganic materials and less than 1 per cent carbohydrates. A molecule of water consists of three atoms, two of hydrogen and one of oxygen. The structure of this molecule has been determined in recent years: each of the two hydrogen atoms is 0.96 Angstrom unit from the oxygen atom (an Angstrom unit is one ten-millionth of a millimeter), and the angle formed by the lines from the oxygen atom to the hydrogen atoms is about 106 degrees. Compared to this simple molecule, a protein molecule is gigantic. It consists of thousands of atoms, mostly of hydrogen, oxygen, carbon and nitrogen. The problem of how these atoms are arranged in a protein molecule is one of the most interesting and challenging now being attacked by workers in the physical and biological sciences.

The proteins are of especial interest not only because of their complexity of structure but also because of their variety and versatility. There are tens of thousands, perhaps as many as 100,000, different kinds of proteins in a single human body. They serve a multitude of purposes: collagen, a constituent of tendons, bones and skin, seems to have the main purpose of providing a framework which has suitable mechanical properties; hemoglobin, found inside of the red blood cells, has the primary function of combining with oxygen in the lungs and liberating it in the tissues; keratin, in the hair and in the epidermis, provides protection for the body, and in the fingernails it functions as a tool; pepsin, trypsin and many similar enzymes are involved in the digestion of food; cytochrome *c* and other oxidation-reduction enzymes catalyze the oxidation of foodstuffs within the cells; the muscle protein myosin plays an important part in the process of converting chemical energy into mechanical work. The tabulation could be continued almost indefinitely.

The Amino Acids

During the second half of the 19th century it was found that proteins can be broken down by boiling them in water for a long time or by treating them with acid or alkali, and that simple chemical substances, called amino acids, can be obtained as the products of this treatment.

Just 50 years ago it was discovered by the German chemist Emil Fischer that proteins consist of long chains of amino-acid residues. (An amino-acid residue is the group of atoms that remains after a molecule of water has been removed from a molecule of an amino acid.) Long chains of amino-acid residues are called polypeptide chains. The chains are usually very large; for example, in the molecule of ovalbumin, the principal protein of egg white, about 400 amino-acid residues form a single polypeptide chain. The number of residues of amino acids of different kinds in a protein molecule can be determined by chemical analysis of the protein; each molecule of ovalbumin has been found to contain about 19 glycine residues, about 35 alanine residues, about 9 tyrosine residues, and so on for the 17 other kinds of amino acids that are represented.

In the study of the structure of a protein there are two questions to be answered. What is the sequence of amino acids in the polypeptide chain? What is the way in which the polypeptide chain is folded back and forth in the space occupied by the molecule? Significant progress has been made toward answering both of these questions during recent years.

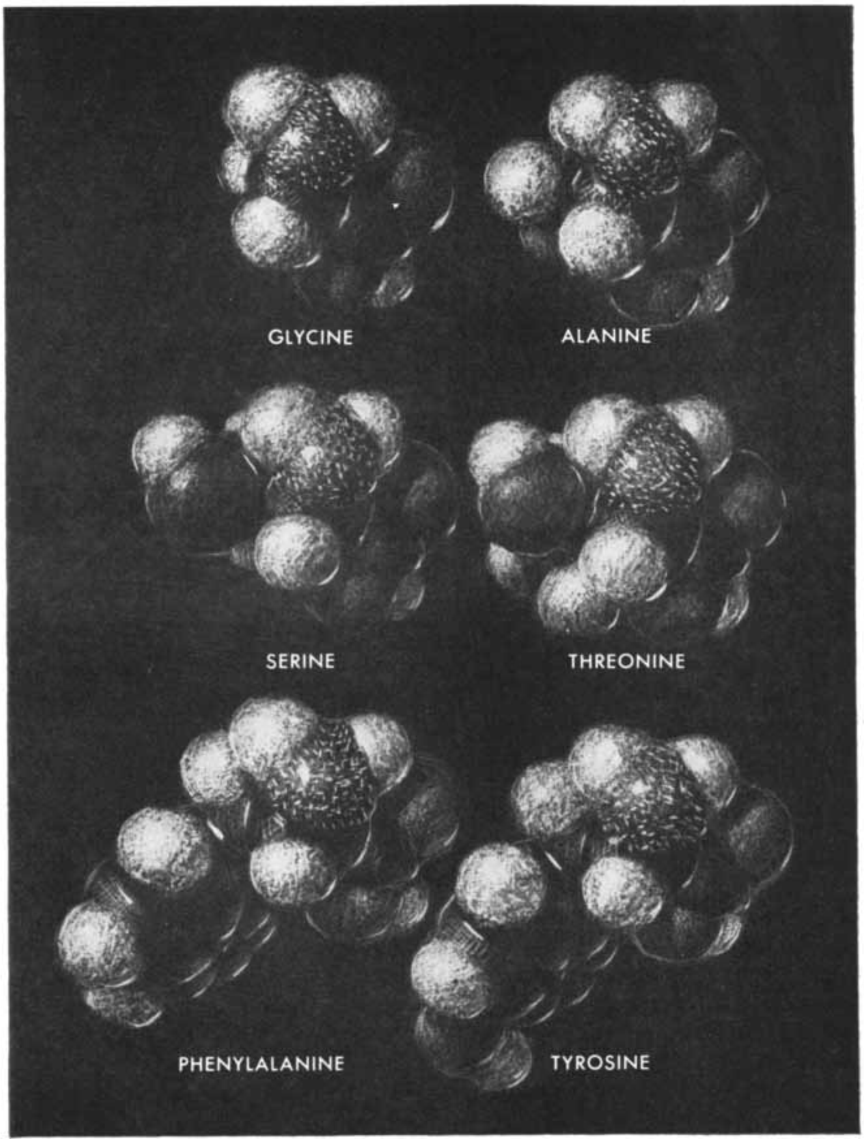
In this article we shall consider only the second question. The experimental technique of greatest value in the attack on this problem is that of X-ray diffraction. It was this technique that in 1914 enabled the Braggs (the late Sir William and his son Sir Lawrence, who is now director of the Davy Faraday Laboratory of the Royal Institution in London) to determine the structure of sodium chloride and other simple substances, and then of more complex inorganic substances, such as silicate minerals and metals, and of organic substances. Only half a dozen years after X-rays were first used for this purpose they were applied to proteins. At the Kaiser Wilhelm Institute in Berlin-Dahlem, R. O. Herzog and W. Jancke made X-ray diffraction photographs of hair, horn, muscle, silk and tendon. The results were disappointing—the definition of the photographs was so poor that it seemed a hopeless job to attempt to determine from them the positions of atoms.

Proteins and X-Ray Diffraction

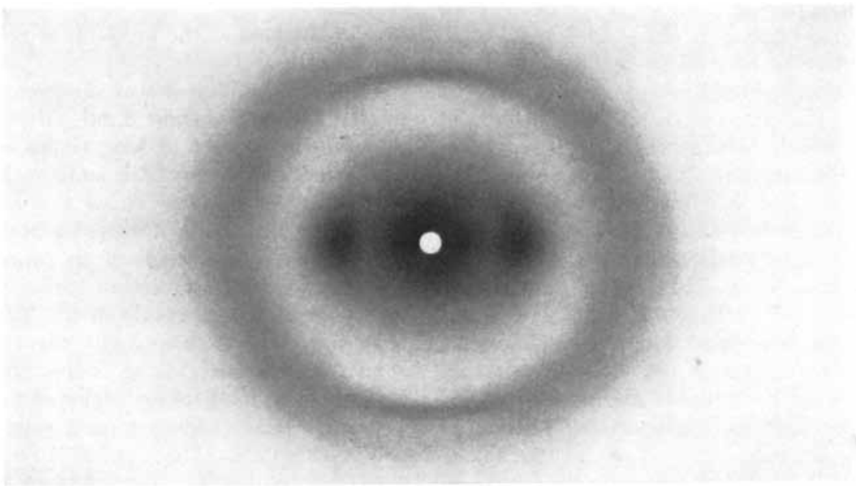
The situation the investigator had to face is suggested by the two photographs at the bottom of these two pages. The photograph on the opposite page shows the diffraction pattern obtained by passing a beam of X-rays through a small crystal of the simple substance glycylglycine which was being rotated about a vertical axis. The photograph on this page shows the diffraction pattern of a fibrous protein, a horsehair that has been descaled (to remove a protein of a different sort that is present on the surface of the hair). The axis of the hair is vertical.

The X-ray photograph of glycylglycine shows about 400 spots. Each of these spots represents a direction in which X-rays are strongly scattered by the atoms in the crystal. From several photographs of this sort a collection of about 800 characteristic intensity values can be obtained. The glycylglycine molecule contains nine atoms other than hydrogen atoms; the hydrogen atoms do not scatter X-rays very strongly, and their positions are usually not well indicated by the X-ray method. The structure of the glycylglycine crystal can be described when three coordinates, the x, y and z coordinates, have been determined for each of the nine atoms. There are accordingly 27 atomic coordinates to be determined. The intensity of each X-ray reflection depends upon these coordinates, and it is possible from the 800 intensity values to determine all 27 of them with considerable accuracy. In this way each of the atoms, except the hydrogen atoms, in the glycylglycine crystal has been located to within about 0.02 Angstrom unit. This uncertainty is about 2 per cent of the distance between each atom and its nearest neighbors. The structure of the glycylglycine crystal, found in this way, is shown on page 54.

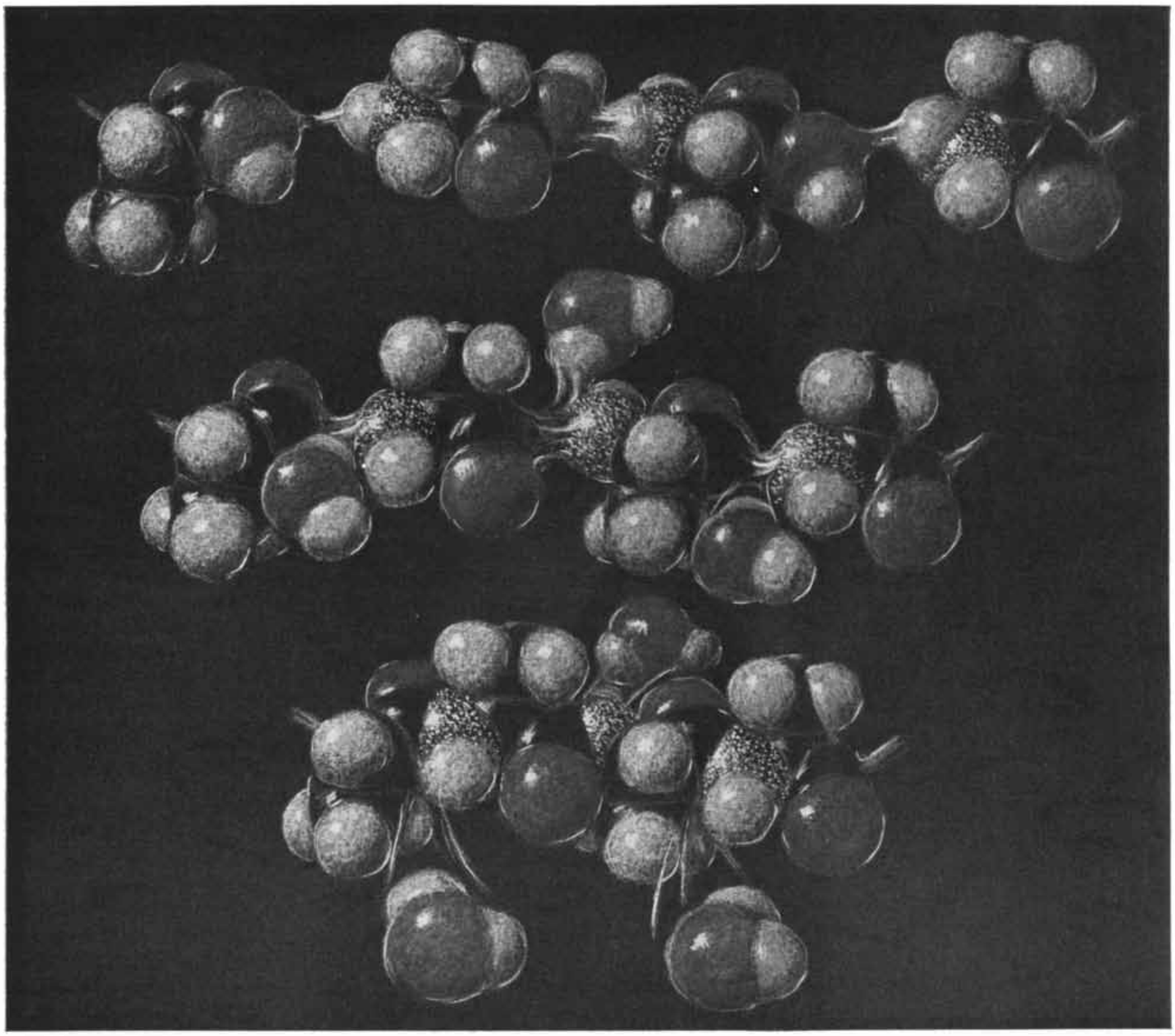
The problem of determining the structure of a protein such as keratin, which makes up the fibers of hair, is a quite different one. The polypeptide chains in fibrous proteins are about as complicated as those in ovalbumin. Chemical analysis of hair has shown that 18 different amino acids are represented in the keratin molecule, and that the repeating unit in the keratin fiber probably consists of about 300 amino-acid residues. Each amino-acid residue contains on the average about nine atoms other than hydrogen; there are accordingly about



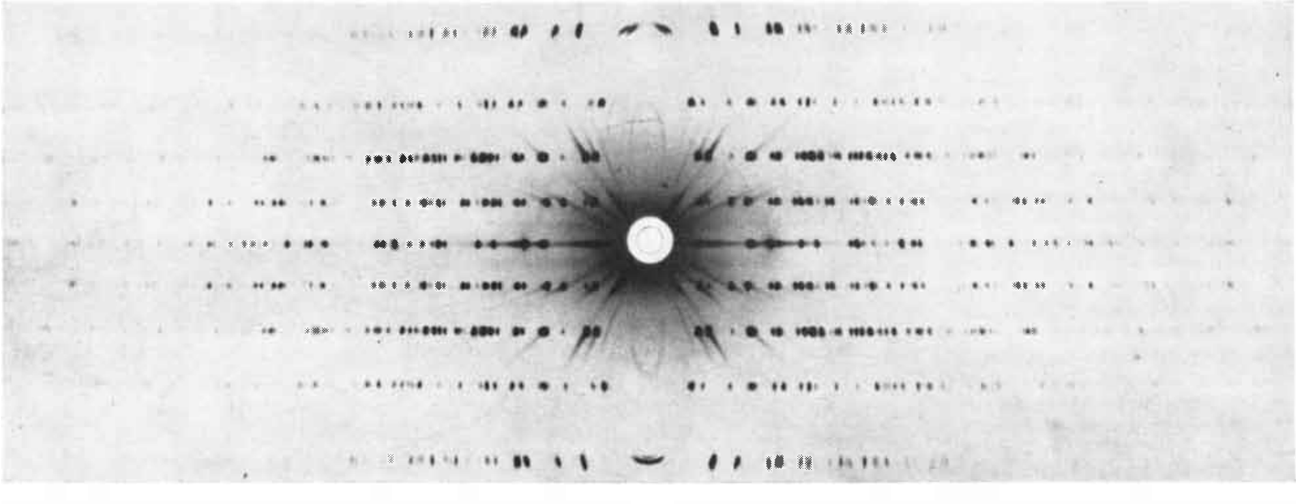
AMINO-ACID MOLECULES are typical of those of the 20-odd amino acids now known. These molecules consist of atoms of carbon (*black spheres*), oxygen (*gray*), hydrogen (*white*) and nitrogen (*stippled*). They differ only in side-chains attached at the left.



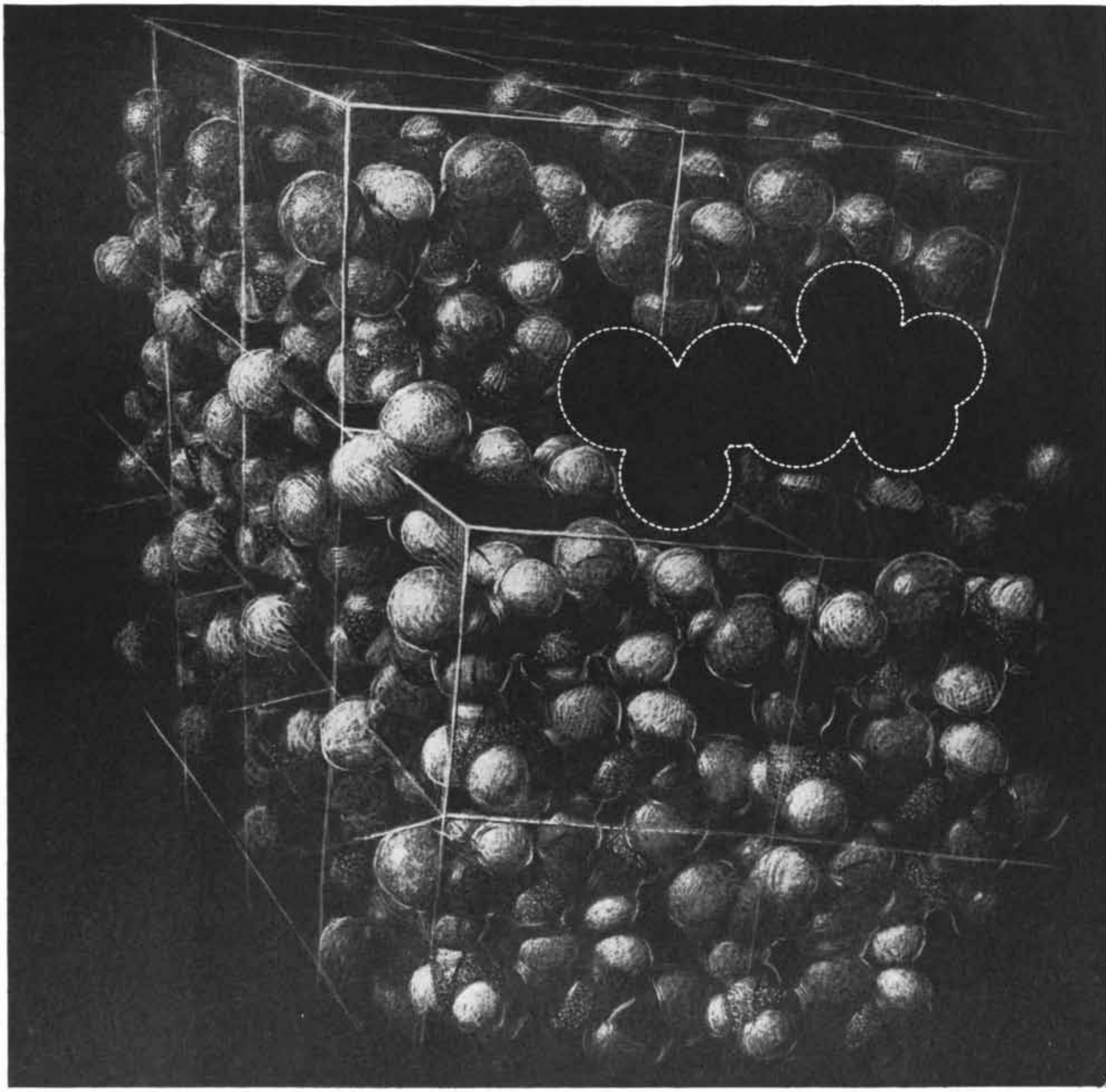
DESCALED HORSEHAIR produced this X-ray diffraction pattern. The X-rays were perpendicular to the plane of the picture; the hair, vertical in a plane parallel to the picture.

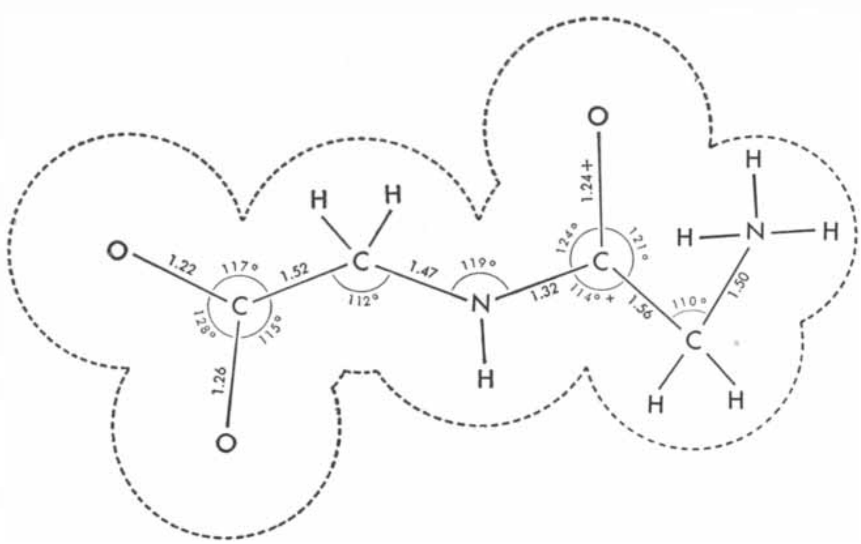


POLYPEPTIDE CHAIN is formed when a hydroxyl group (one atom of hydrogen and one of oxygen) attached to a carbon atom in an amino-acid molecule combines with a hydrogen atom attached to a nitrogen atom in another amino-acid molecule (*top*). This forms a molecule of water. As the water is ejected the carbon and nitrogen atoms combine to link the amino-acid residues (*bottom*).



GLYCYLGLYCINE CRYSTAL yielded an X-ray diffraction pattern with a regular array of spots. As the crystal was photographed it was rotated around its *c* axis, which was vertical in a plane parallel to that of the picture. The *c* axis is one of three crystal axes.

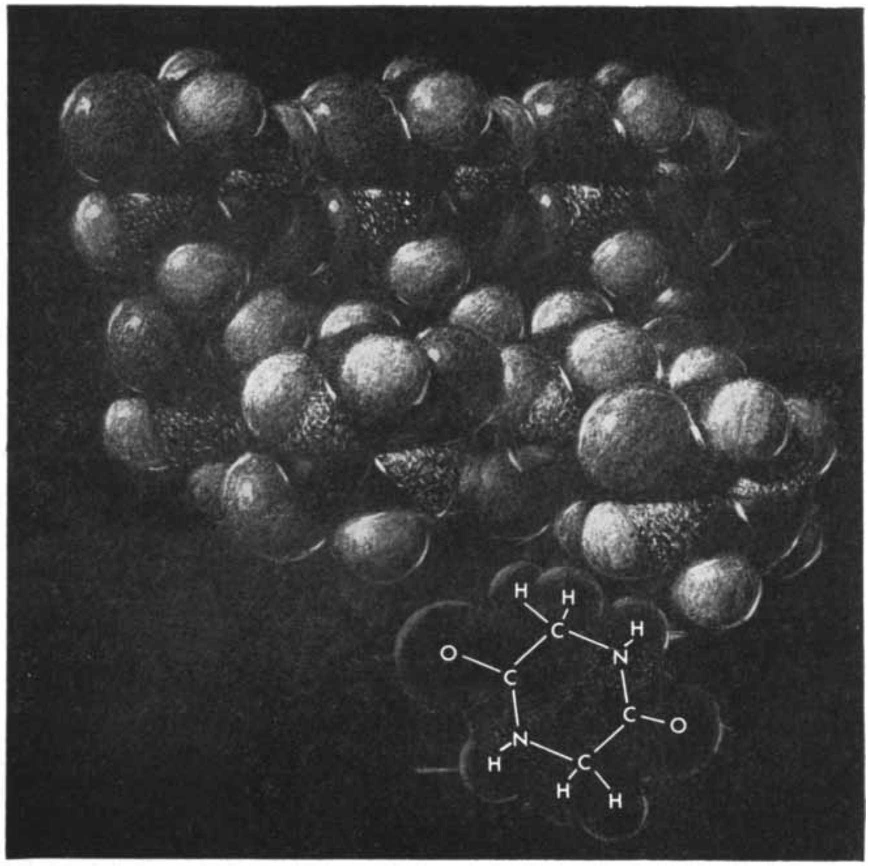




POSITIONS OF ATOMS in a crystal of glycylglycine have been determined from the intensities of spots on X-ray patterns like that at the bottom of the preceding page. The positions of the carbon, oxygen and nitrogen atoms have been determined within 0.02 Angstrom unit. The hydrogen atoms are not accurately located because they do not scatter X-rays very strongly. On the basis of this information it is possible to calculate the dimensions of the glycylglycine molecule. This is outlined in the drawing above and shown in detail by the diagram at the right. The angles between the bonds that join the atoms are indicated in degrees. The length of each bond is given in Angstrom units.

2,700 atoms to be located and 8,100 coordinates to be determined. Such a complex structure obviously cannot be determined from the ill-defined X-ray photograph of horsehair.

Despite this discouraging situation several investigators, most outstanding among them W. T. Astbury of the University of Leeds, continued to use X-rays in the study of the fibrous proteins that occur in plants and animals, and they collected a great deal of valuable information. Herzog and Jancke had observed that the X-ray patterns of hair, silk and tendon are quite different. The later investigators found that almost every one of the many fibrous proteins found in nature gives one or another of these three patterns. Such different proteins as hair, horn, fingernail, porcupine quill, muscle, epidermis, fibrinogen and bacterial flagella give similar X-ray photographs. This similarity strongly suggests that the configuration of the polypeptide chains in all of these proteins is the same; that, regardless of differences in the relative number and sequence of their amino-acid residues, the chains are folded or coiled according to a common pattern. Other fibrous proteins, such as silk and tendon, have different X-ray patterns, and their polypeptide chains must be coiled in different ways.



HYDROGEN BONDS join the molecules of diketopiperazine in long laths. In the model of the diketopiperazine crystal at the top the laths are horizontal. At the bottom is the structure of a diketopiperazine molecule. Hydrogen bonds occur at the points N-H and O-C.

In 1937 it was decided in the Gates and Crellin Laboratories of Chemistry at the California Institute of Technology to attack the problem of the structure of proteins along an indirect route—by learning enough about the nature of polypeptide chains to permit a good guess as to how the polypeptide chain would naturally fold itself to form a protein molecule or fiber. At that time the X-ray diffraction method had been successfully applied in the determination of the structure of hundreds of crystals, including some very complex ones such as the mineral beryl ($Be_3Al_2Si_6O_{18}$). No structure determination had, however, yet been made of any amino acid or any other simple substance closely related to the proteins.

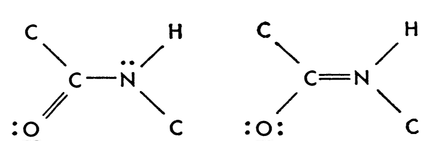
The attack on these simple substances was begun, and by 1950 precise structure determinations had been made in these laboratories of three amino acids, three simple peptides (short chains of amino-acid residues), and several closely related substances. With the information provided by these structures it was possible to start work on the prediction of likely configurations for polypeptide chains. Since 1950 six more amino-acid and peptide structures have been determined at the California Institute of Technology, and several have been worked out in other laboratories also.

Much work was needed to learn the distances between the atoms, the angles between the chemical bonds, and other structural features. This had to be done with an accuracy corresponding to errors in atomic position not greater than about 0.02 Angstrom unit. The investigation of one crystal, the amino acid threonine, required the efforts of four post-doctoral research workers for an average of one full-time year apiece.

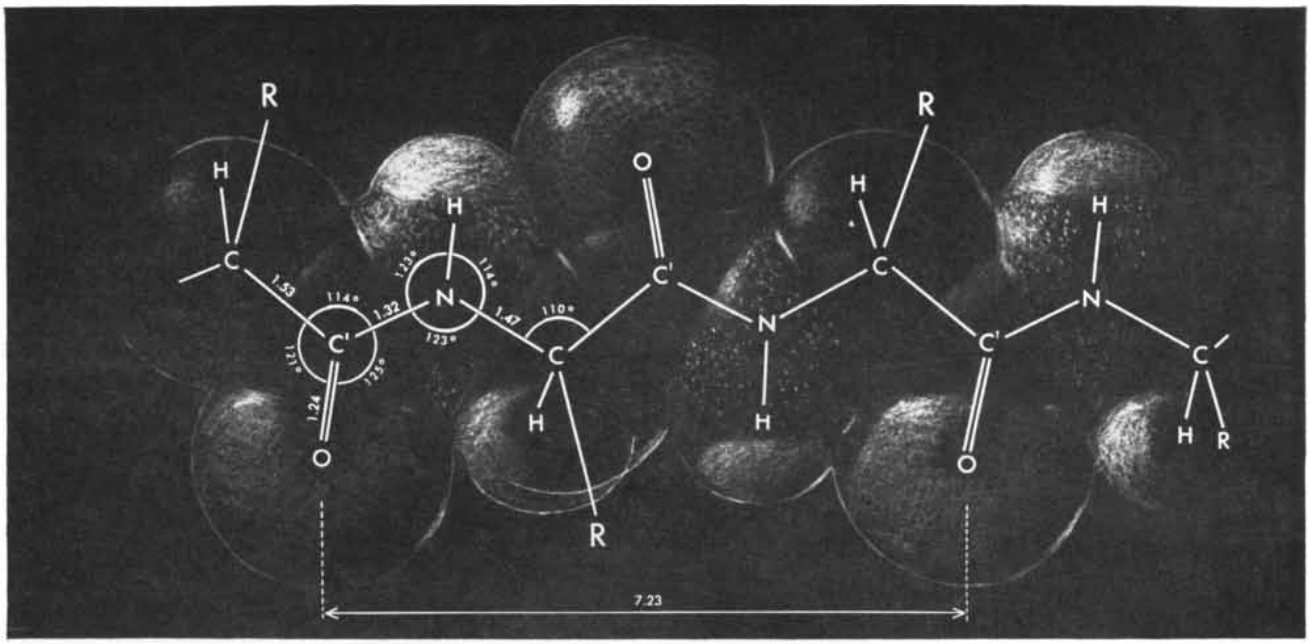
When several of these structures had been determined it was found that they were strikingly uniform from substance to substance. This uniformity permitted the reliable prediction of the dimensions of a polypeptide chain. The dimensions of the chain, as derived in this work, are given in the illustration at the top of the next page. The distances between atoms are believed to be reliable to about 0.02 Angstrom unit, and the angles between chemical bonds to within about three degrees.

One characteristic feature of the structure is of special importance. The six atoms of the so-called amide group (CCONHC) are coplanar—they lie within a few hundredths of an Angstrom unit of a common plane. This planar amide group is a rigid part of the polypeptide chain; the amide group can be only slightly distorted from the planar configuration. The rigidity of the amide group greatly simplifies the problem of finding the ways in which the polypeptide chain can be folded.

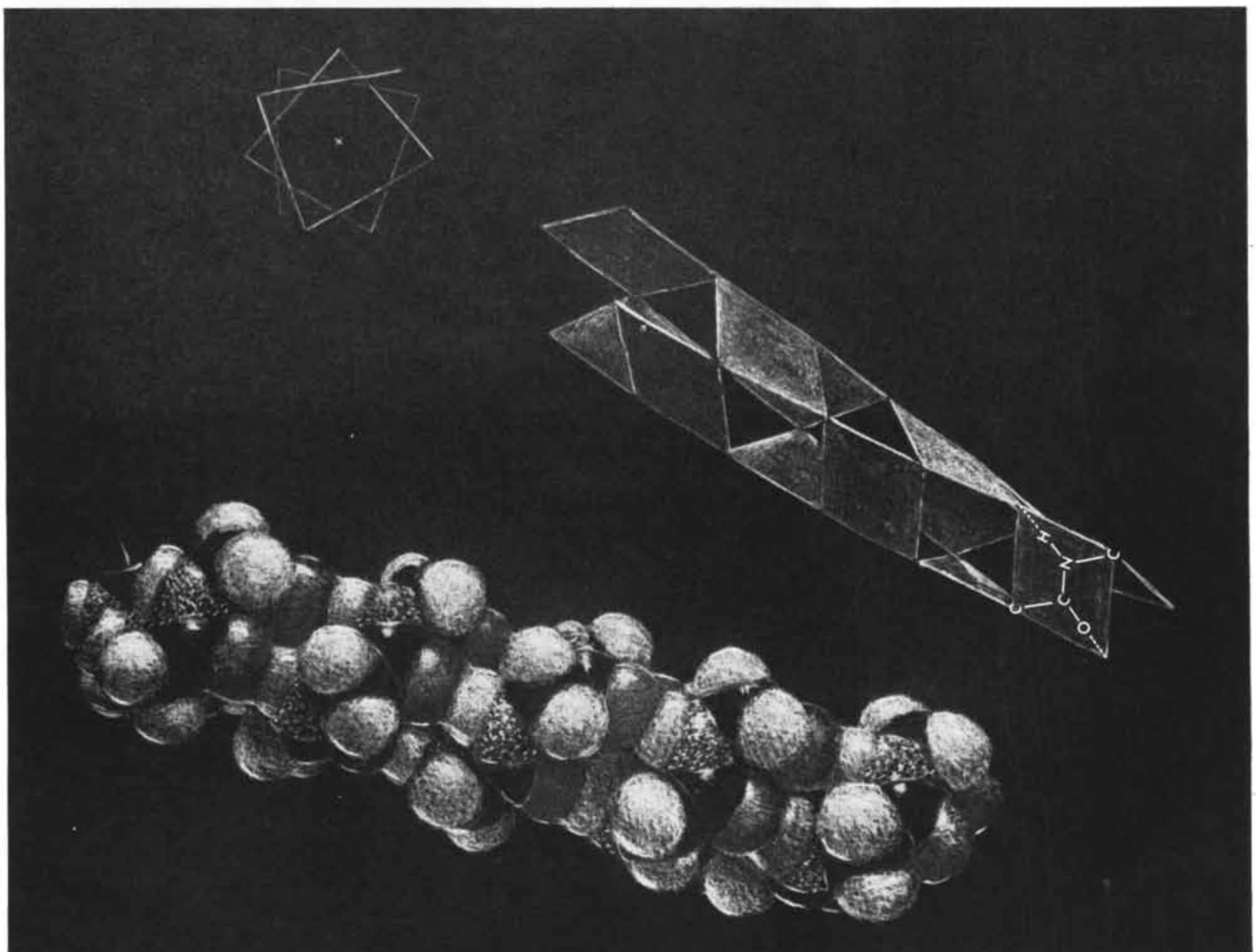
The planarity of the amide group is explained by its electronic structure. The chemical valence bonds can be represented for this group in two different ways:



In one valence-bond structure there is a double bond between a carbon atom in the group and the adjacent oxygen atom. In the other valence-bond structure there is a double bond between the same carbon atom and the adjacent nitrogen atom. The actual structure of the amide group may be described as



POSITIONS OF ATOMS in a polypeptide chain have been determined by precise X-ray analysis of amino-acid and peptide crystals. The angles between bonds are in degrees. Linear dimensions are in Angstrom units. The symbol R represents atoms in side chains.



ALPHA HELIX is an arrangement of the polypeptide chain characteristic of hair, horn and related proteins. As shown at the upper right, the flat amide groups of the chain are joined by carbon atoms and held in place by hydrogen bonds. At the upper left this configuration is seen along its axis. At the bottom is a model of the helix. For simplicity the amino-acid residues are those of glycine.

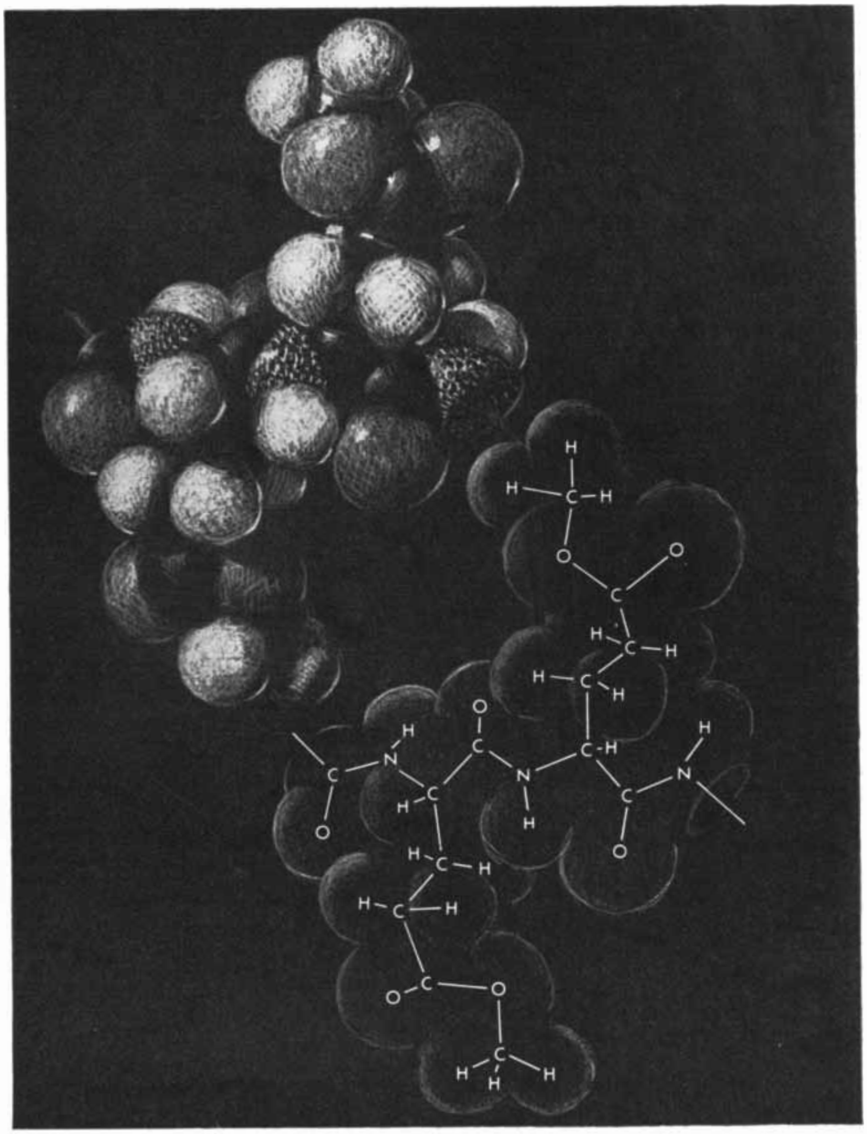
a hybrid of the two valence-bond structures, with the double bond resonating between the two positions.

There are two alternative ways in which the atoms of the amide group can be arranged in a plane. One is called the trans configuration; in it there are carbon atoms at opposite corners of the group. The other is the cis configuration, in which the carbon atoms are at adjacent corners. The trans configuration appears in the structure of a polypeptide chain shown at the left, and the cis configuration in the structure of the substance diketopiperazine on page 55. There is evidence that the trans configuration is considerably more stable than the cis configuration, and the cis configuration is probably rare in the polypeptide chains of proteins.

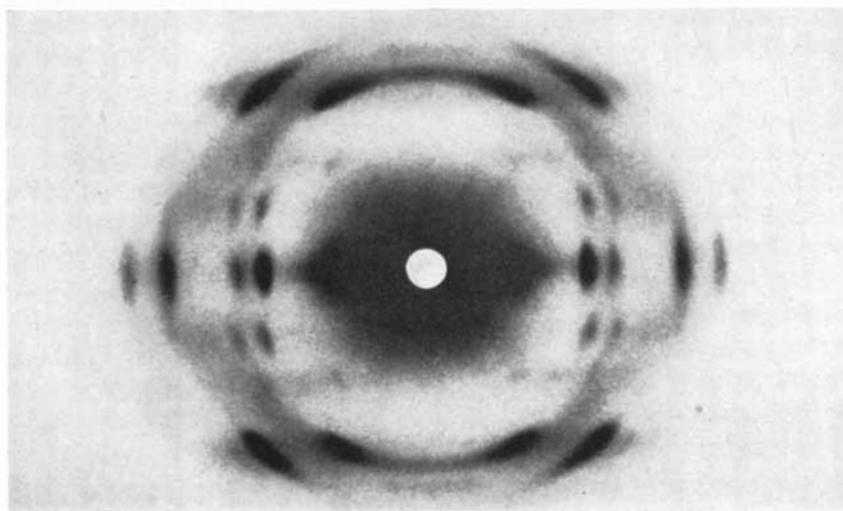
A polypeptide chain of amide groups with the trans configuration might be folded in a great many ways. The bonds to the corner carbon atoms of the group are single chemical bonds, and the molecule may assume any one of various angles about the axis of each single bond. Of the resulting configurations, the satisfactory ones are those in which each amide group forms so-called hydrogen bonds with other amide groups. The hydrogen bond between two amide groups is a weak bond connecting a hydrogen atom and a nitrogen atom of one amide group with the oxygen atom of the other amide group. In the illustration on page 55, hydrogen bonds join the molecules of diketopiperazine into long laths, which lie side by side in the crystal. The presence of the hydrogen-bonded laths of diketopiperazine molecules is reflected in the physical properties of the crystal. One would expect that it would be rather easy to separate one lath from another, and more difficult to break a lath, which would require that the hydrogen bonds be broken. It is in fact found that the diketopiperazine crystal can easily be cleaved along planes parallel to the long axis of the laths.

By studying this crystal and others it has been shown that the average distance between a nitrogen atom and an oxygen atom connected by a hydrogen bond is 2.79 Angstrom units. It is accordingly reasonable to believe that an acceptable configuration for a polypeptide chain should be one permitting the formation of hydrogen bonds about 2.79 Angstrom units long.

The folding of the polypeptide chain that seems to occur most widely among proteins is shown in the illustration at the bottom of the opposite page. This



SYNTHETIC POLYPEPTIDE poly-gamma-methyl-L-glutamate is depicted in this model. The polypeptide chain is horizontal. Only two of the residues in the chain are shown.



X-RAY DIFFRACTION PATTERN of a specially oriented sample of poly-gamma-methyl-L-glutamate was made by the English investigators C. H. Bamford, W. E. Hanby and F. Happey. The axis of the synthetic fiber was vertical in a plane parallel to that of the picture.

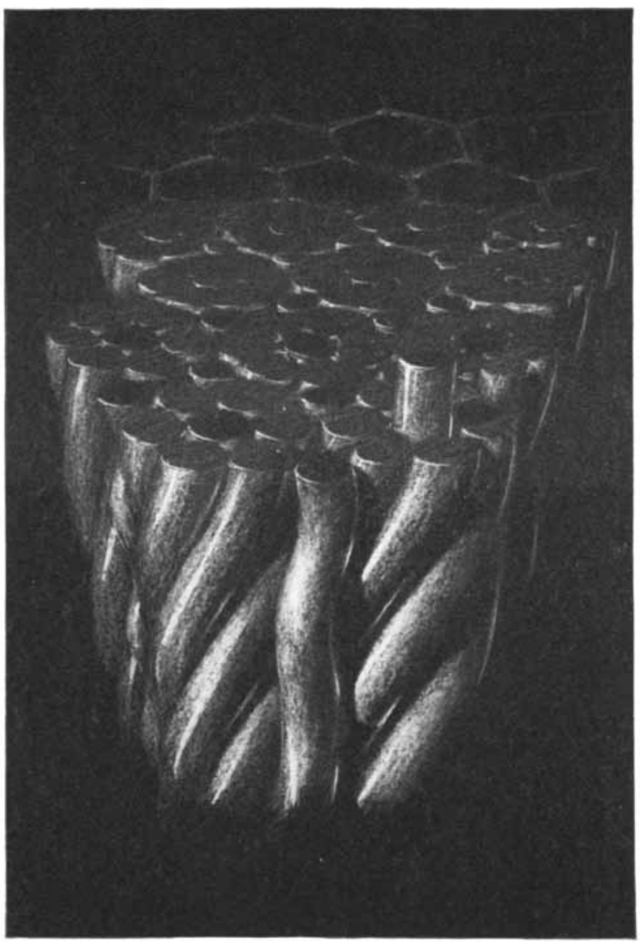
configuration was discovered by analyzing the consequences of a simple assumption—that all of the amino-acid residues in the polypeptide chain are equivalent to one another, except for the difference in the nature of the side chains. Except for glycine the amino acids that occur in proteins are asymmetric; they are described as left-handed molecules. When asymmetric objects in space are joined together in such a way that every one has the same geometrical relationship to its neighbors, a helix is formed. An example is provided by a spiral (properly a helical) staircase; the first step is converted into the second step by moving it along the axis of the staircase and rotating it around the axis. The same operation converts the second step into the third, the third into the fourth and so on. When a search was made for helixes in which each amide group in the polypeptide chain is attached by hydrogen bonds to two others, two structures were found. One of these structures does not seem to occur in proteins. The other structure, which is called the alpha helix, is believed to be present in many proteins.

The Alpha Helix

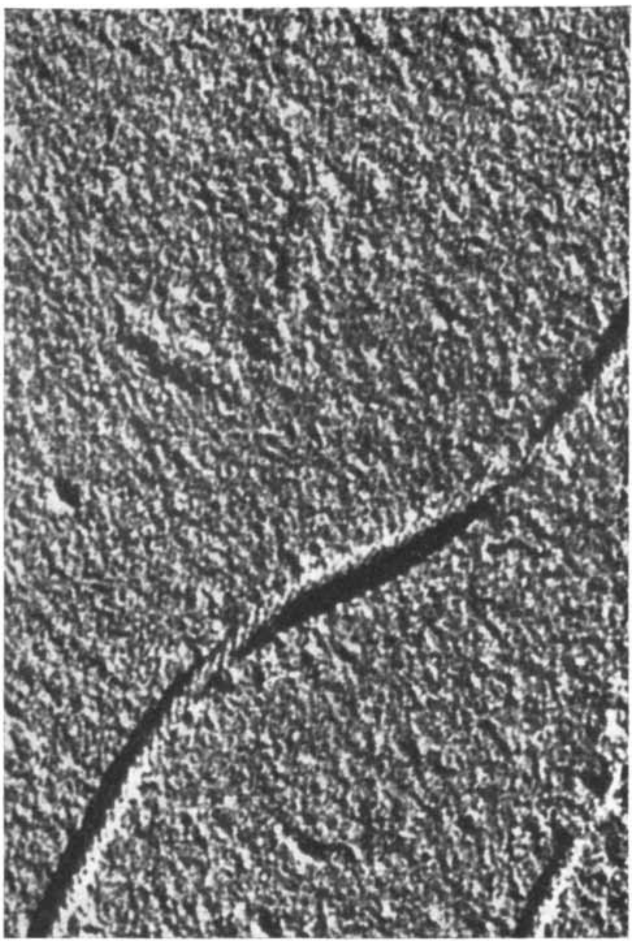
The alpha helix has about 3.60 amino-acid residues per turn of the helix. This number may vary by a small amount. The original prediction was that the number of residues per turn would lie between 3.60 and 3.67. The reliable experimental values that have been obtained so far lie between 3.600 and 3.625. The number 3.60 corresponds to 18 residues in 5 turns of the helix. The pitch of the helix—the distance between one turn and the next turn—was predicted to be 5.4 ± 0.1 Angstrom units. This value corresponds to 1.50 ± 0.03 Angstrom units for the axial length per amino-acid residue—the rise from one step of the helical staircase to the next. The diameter of the molecule, including the side chains, was predicted to be about 10.5 Angstrom units.

It was immediately seen that the alpha helix might represent the structure of hair, fingernail, horn, muscle and other proteins classified as alpha keratin. However, the agreement between the X-ray pattern predicted for molecules of this configuration, lined up side by side in parallel orientation, and the observed X-ray diagram was far from complete. Encouraging support then came from an unexpected quarter. The English investigators C. H. Bamford, W. E. Hanby and F. Happey had prepared X-ray photographs of some synthetic polypeptides in which all of the amino-acid residues in the polypeptide chain were chemically identical, and they published these photographs early in 1951. One of them, together with the structural formula of the substance, is shown on the preceding page. This photograph agrees very well with the calculated X-ray pattern for a bundle of alpha helixes arranged in hexagonal packing. In particular, the positions and intensities of the X-ray reflections correspond very closely to the calculated values for a helix with 18 amino-acid residues in 5 turns.

There is a general similarity between



HAIR and similar proteins are probably made up of seven-strand cables. Each consists of an alpha helix surrounded by six compound helixes. In the interstices are compound helixes of different pitch.



BACTERIAL FLAGELLUM in this electron micrograph is a three-strand cable 180 Angstrom units thick. The diameter of each strand suggests that it is a seven-strand cable of seven-strand cables.

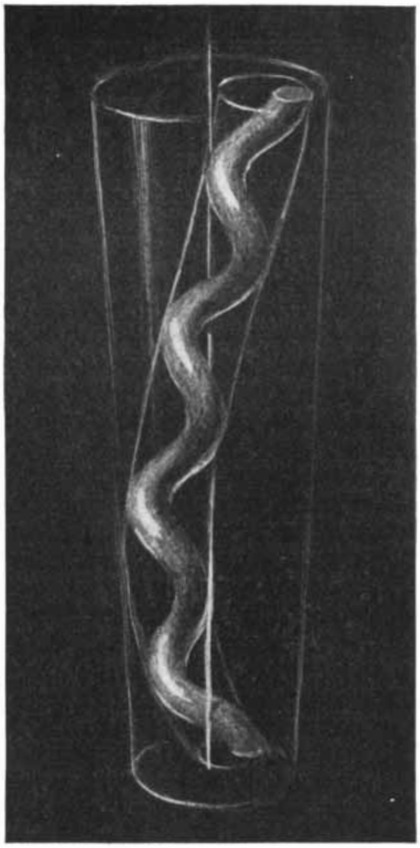
the X-ray photograph of the synthetic polypeptide and the pattern of horsehair on page 52. This lends some support to the idea that alpha helixes are present in hair as well as in synthetic polypeptides, but the similarity is not close enough to be reliable. The convincing proof was provided by Max Perutz of the Cavendish Laboratory at Cambridge University. He pointed out that a strong X-ray reflection corresponding to a spacing of 1.5 Angstrom units should be observed for substances containing the alpha helix; the amino-acid residues, which are separated from one another by a distance of 1.5 Angstrom units along the axis of the helix, would cooperate with one another in scattering X-rays in the direction corresponding to this reflection. Perutz made X-ray photographs of synthetic polypeptides and many proteins, with the fibers oriented at the correct angle for this reflection to appear on the photographic plate, and he found that the reflection was in fact produced by the synthetic polypeptides and by hair, horn, fingernail, epidermis and other proteins which give X-ray photographs of the alpha-keratin type.

One striking difference between the X-ray photograph of horsehair and the expected pattern for an arrangement of alpha helixes in hexagonal packing is the presence of a strong reflection above and below the central image. In the corresponding photograph of the synthetic polypeptide there are strong reflections on either side of these points. About a year ago it was suggested independently by the workers at the California Institute of Technology and by F. H. C. Crick of Cambridge University that the strong vertical reflections result from the presence of molecules with the configuration of the alpha helix which are twisted about one another, to form what Crick calls coiled coils. This twisting of the alpha helix into a compound helix, shown at upper right, might result from a small shortening and lengthening of hydrogen bonds, perhaps within the range 2.7 to 2.9 Angstrom units, in a regular way. A good correlation of all of the evidence is provided by the structure for alpha keratin shown in the illustration at the left on the opposite page. In this structure there are seven-strand cables, each about 30 Angstrom units in diameter, which are made up of six compound alpha helixes twisted about a central alpha helix. These seven-strand cables are arranged in hexagonal packing, and the interstices between them are occupied by additional alpha helixes.

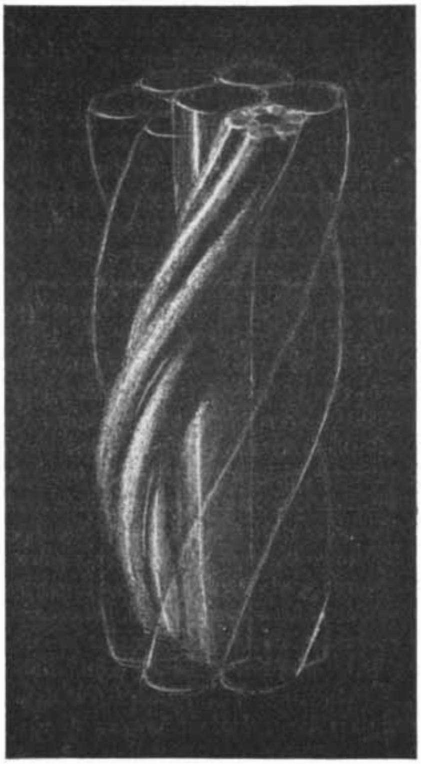
It is of course evident that the X-ray photograph of horsehair does not provide enough information to settle the question of the structure of alpha keratin in complete detail. There seems to be little doubt, however, that hair and similar proteins are made up of polypeptide chains with the configuration of the alpha helix and that these chains are twisted about one another. It is not unlikely that the way in which the chains are twisted together is the one shown at the right, but there is a possibility that it may be somewhat different.

The simplicity of the helix as a structural element—the fact that it results automatically through the repetition of the most general symmetry operation which does not convert an asymmetric object into its mirror image—tempts us to look for helixes in larger structures. An example is given in the illustration at the right on the opposite page. This is an electron micrograph of a bacterial flagellum, from a bacterium of the diphtheroid class, made by Robley C. Williams and Mortimer P. Starr of the University of California in Berkeley. X-ray photographs of such flagella are of the alpha-keratin type, indicating the presence of alpha helixes. This flagellum is about 180 Angstrom units in diameter. It may be seen in the electron microscope that it consists of three strands, each 90 Angstrom units in diameter, twisted about one another. Although the way in which these strands are built out of alpha helixes is not known, one speculation immediately suggests itself. The seven-strand cables mentioned earlier are 30 Angstrom units in diameter; if a seven-strand cable were similarly made of seven of these seven-strand cables it would be 90 Angstrom units in diameter. Hence it may be found, when these flagella are subjected to more thorough study, that they can be described as three-strand ropes, each strand of which is a seven-strand cable built of seven-strand cables of alpha helixes. It is interesting that the bacterial flagella themselves form a still larger helix.

Through the development during the last quarter-century of the techniques of electron microscopy and X-ray diffraction, the time has now arrived when it is possible to track the structure of living organisms down through successively smaller orders of size, without a gap, from the whole animal through the cell to the atom. We may hope that the knowledge that will be obtained in this way during the coming decades will provide a far more precise and penetrating understanding of life than we now have.



COMPOUND HELIX, or coiled coil, is the probable configuration of the polypeptide chain in hair, horn and related proteins.



SEVEN-STRAND CABLE made up of seven-strand cables, proposed for strand of a bacterial flagellum, might have this structure.

THE HOME LIFE OF THE SWIFT

The European species is so much at home in the air that it eats, drinks and mates on the wing. This aerial existence has certain disadvantages, compensated by unusual evolutionary adaptations

by David and Elizabeth Lack

The old books on birds started with the eagle because he, by virtue of his strength and size, was king of the birds. But in the 19th century kings were tumbled from their thrones by black-coated republican intellectuals, and the bird books followed suit. The birds of prey were dismissed as primitive, and the crow and its relatives were honored as the most intelligent and social of birds. Ours is sometimes called the century of the common man, and the modern order of birds appropriately reaches its climax with the weaver finches, of which the most familiar is the humble and town-loving English sparrow. Perhaps now, in an age characterized by fast travel and intricate machines, it is time to select as pre-eminent that bird which excels where birds are most at home—in the air. For this honor the bird known as the swift is the strongest candidate.

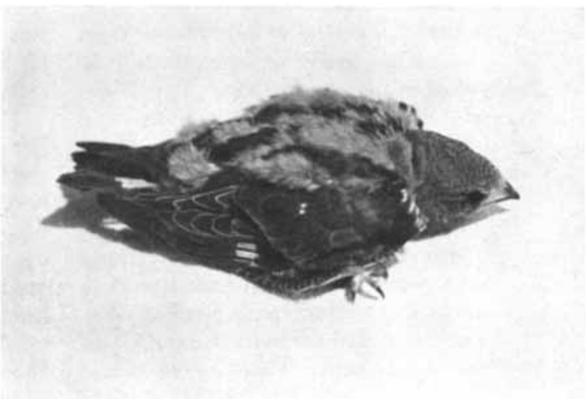
The swift spends almost its entire life on the wing. Swifts gather all their food and nesting material in flight, they drink by skimming over the surface of still water, they mate in mid-air, they may even pass the night without roosting. They never set foot on the ground except when hurt; they nest and rest in holes in trees, cliffs or buildings. They are the most aerial of all birds.

The swift has wings that are long, thin and curved somewhat backwards, the shape best adapted to rapid flight. Still it can maneuver more skillfully than other long-winged birds. This is because the wing of the swift is mostly supported on the bones of its large "hand," leaving its relatively small upper arm free to act as a joint with which to rotate the wing as a whole. In most small birds the bones of the forearm, midarm and hand are about equal in length; on the upstroke the wing is folded at the wrist and the flight feathers are opened. In the swift the flight feathers are locked together, and the wing is as stiff as a paddle. On the upstroke its leading edge is turned backward. Only the hummingbird, which is related to the swift, flies in a similar fashion.

The aerial life of the swift has certain drawbacks. Swifts have such long wings and short legs that their takeoff from the ground is very slow. This limits their choice of nesting sites to places above the ground which have a clear drop to permit a rapid takeoff. Further, because swifts find all their food in the air, they are dependent on fine warm weather. Under cold, wet or windy conditions insects are scarce in the air and swifts have great difficulty in finding enough food.

It is therefore not surprising that nearly all the 70 species of swifts are tropical. Only two, the common swift of Europe and Asia and the chimney swift of North America, breed in the cool temperate zone, and even these stay just for the summer. In winter they retire to the tropics. Here we are concerned with the European bird, and the reader should bear in mind that the chimney swift and other species have rather different habits, particularly at the nest.

We started our observations of the swift in a quiet English village near Oxford, where the birds nested in the thatched roofs of cottages. Unhappily we could reach the nests only from the out-



GROWTH of the European swift is shown in these five photographs. In the first photograph the young bird is just out of the shell. In the second photograph it is 10 days old; in the third, 20 days old; in the fourth, 30 days old. In the last photograph the bird is 40 days side with the help of ladders, and so we made little headway. Later we received permission to study 20 pairs of swifts living 100 feet above the ground in the tower of our own Oxford University Museum of Zoology. In winter, while the swifts were in Africa, we substituted boxes for the ventilators in which they nested. We then built a platform inside the tower and set up ladders which gave access to it. When the swifts returned for the summer, they accepted the change without disturbance and our detailed studies began. We found the parents remarkably tame. This is probably because they normally nest in holes that are closed at the rear, and thus have evolved no response to an enemy coming at them from the rear. The birds soon got quite used to us and allowed us to take their eggs or young from them and put them back again without any fuss. Later we were even able to place bands on the parent birds, provided we did not lift them from the floor of the box.

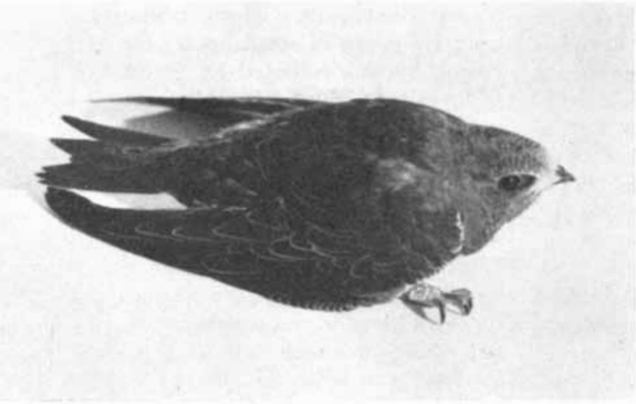
Next winter we went a step further, taking out the wooden backs of the boxes and replacing them with glass. The tower was almost dark, the only light coming from the entrance holes of the boxes themselves. We could now sit in the half-darkness and watch the swifts from, if necessary, a range of a few inches. It was fascinating to study the birds at such close quarters, and to know that we were the first to observe many of their breeding habits. Indeed, it was hard to believe they were the same creatures that outside the tower could be seen dashing madly through the air.

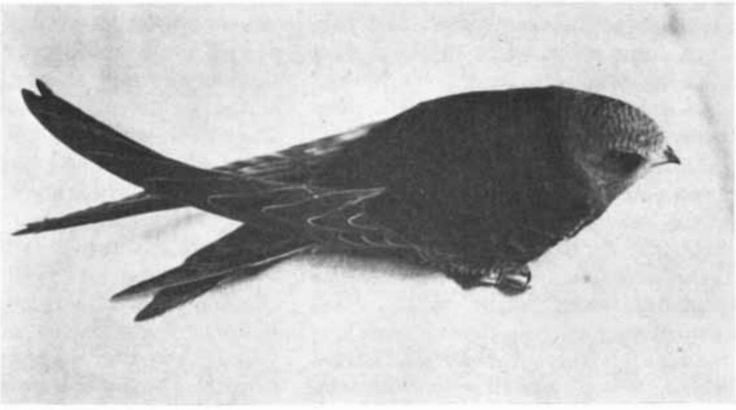
The swifts arrive at the beginning of May and at once occupy their boxes. Banding shows that each swift normally pairs with its mate of the previous year, but, since the birds usually return on different days, they perhaps rejoin each other merely because they have come back to the same box as before. After pairing, however, they recognize each other. If a strange bird enters the box it is immediately attacked. Early in the season strange birds sometimes try to drive the owners from their boxes, and violent fights occur. Among most wild birds fighting takes the form of song and display without actual blows. But in the half-light of their holes swifts cannot use such refined methods. Instead they grip each other tightly with their sharp-pointed claws and peck each other with their beaks. Sometimes they remain locked together for as long as five hours, until one bird drags the other to the entrance of the nest and both fall out. The performance is less dangerous than it looks, for the birds nearly always grip each other by the legs, where they do no harm, and their beaks are so soft that the pecks are almost harmless!

Courtship, again because it happens in semidarkness, is simple compared with that of most other birds. The chief display is for each bird to preen the other on the throat and neck, the parts which a swift cannot reach for itself. This mutual preening is accompanied by a soft, high-pitched clucking. The birds also mate in the boxes, but despite much watching we saw them do so only occasionally. On the other hand, there are many reports of one swift diving on to the back of another in the air, both then descending with screams. It has long been disputed whether this aerial encounter is mating. We conclude that it is because it occurs only at the same season of the year (late May) and at the same times of day (around 8 a.m. and 6 p.m.) as mating in the boxes, and because the latter is uncommon. So far as is known, swifts are the only birds which mate in this fashion.

Because the swift collects the material for its nest from the air, it does so chiefly in windy weather. With its beak it catches feathers, leaves, straw, the aerial seeds of certain trees, flower petals, scraps of paper and other objects. Both male and female swifts collect this aerial flotsam, and, unlike most birds, they continue adding to the nest as they incubate their eggs. The nest material is cemented in place with saliva, as it is by other swift species. (The saliva of a cave-dwelling Oriental swift provides the basis for the well-known Chinese "bird's nest soup.")

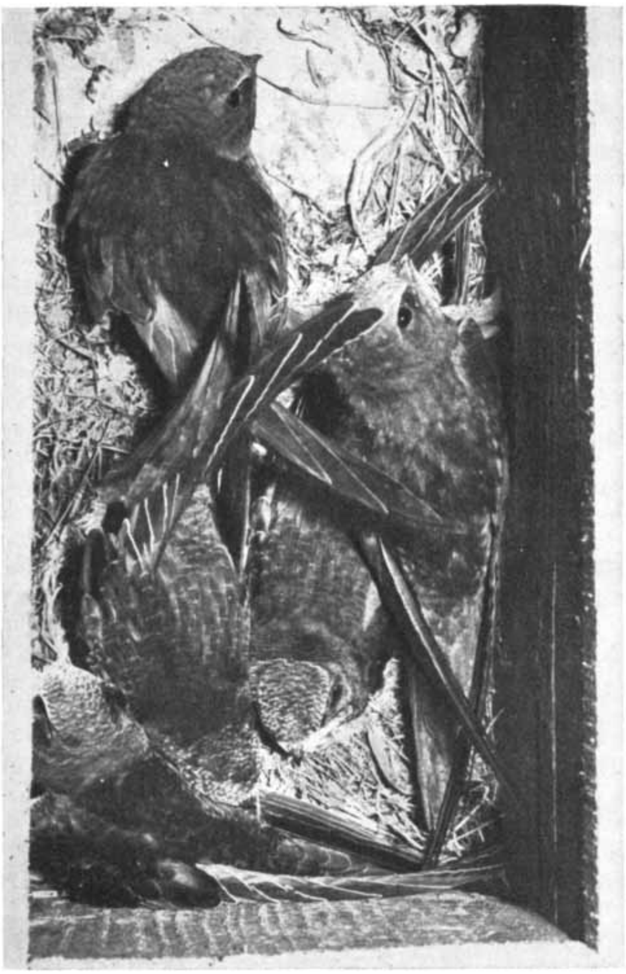
The eggs are white, like those of other birds which nest in dark places. During the day one parent sits on the eggs while the other is out feeding, and later they change places. In fair weather, when insects are plentiful in the air, the bird that is out feeding quickly collects enough of them and may return in less than half an hour. In cold or windy weather it may have to hunt more diligently, and its mate may be left sitting for as long as five hours. If it is alone for a very long time, the sitting bird goes out to feed without waiting to be relieved, presumably because its need for food is so great. The eggs may then be left uncovered for several hours. Because this happens mostly in cold weather we wondered what might happen to the eggs, but to our surprise they hatched normally. No other bird which nests in cool regions leaves its eggs unincubated for such long periods without harm. Apparently evolution has adapted the swift's eggs to withstand cooling, and the same applies to the newly hatched and naked young. When we first found young birds cold and unattended, we thought the parents had deserted them, but it was merely that both parents were out hunting. Provided that enough food





old and has reached its adult length of about seven inches. Although swifts were observed in the nest by the authors, these and the other photographs that illustrate this article were made during similar observations by E. Weitnauer of Oltingen, Switzerland.

FLEDGLING and its mother were photographed in a nest from which the top had been removed. The younger bird is marked by the white feathers on the top of its head. The next day it left the nest.



ENTIRE FAMILY gathered in the nest on a rainy day. On such days both the parents and their young go hungry because there are few insects in the air, which is the only place swifts can catch them.

was found, the young came to no harm.

Both parents feed the young. Most insect-eating birds bring one or a few insects to their nestlings every few minutes, but the insects taken by the swift are so small, and the birds may have to travel so far to collect enough of them, that the interval between feedings is much longer. In good weather each parent returns about every three quarters of an hour; in poorer weather, only about once in three hours; in bad weather the interval is longer still. The feeding parent gradually collects a large number of insects, still alive but entangled in saliva, in the back of its throat. By the time a swift is ready to return to its young, its throat is so distended that it looks like a miniature pouter pigeon. A single ball of food weighs more than a gram and contains anywhere from 90 smallish insects to 800 very small ones. When the bird returns to the nest, the whole ball is passed to one of the nestlings, which may thus gulp down in one mouthful up to 10 per cent of its own weight in food. Only when the young are very small does the parent share the food among them.

We found that, if we took a nestling from the box just after it had been fed, we could manipulate the food from its throat, and in this way we were able to analyze the insects collected by the parent. We learned that they included almost every type of insect to be found in the air except butterflies and most dragonflies, which are too large for the throat of a swift, and thrips and other minute forms, which are presumably too small to be seen by a swift on the wing. The swift of course does not fly at random with its mouth open, but uses its eyes and departs from its course if it sees an insect. It also searches in likely places. When the weather is good and the wind moderate, swifts like to cruise up and down the windward side of a row of trees bordering open ground. This is because insects are blown against the trees and then up, and so are concentrated there. In windy and wet weather, when few terrestrial insects rise into the air, swifts hunt over open water, because then May flies and other aquatic insects emerge.

We were able to measure the feeding efficiency of certain parent swifts we knew well. One bird was out of the box for 64 minutes, after which it brought back 1.7 grams of small insects for its young. Another collected 1.2 grams, in addition to anything it may have eaten itself, in 47 minutes. We reckoned that on a fine day each pair came back with about 50 grams of insects. When the birds cannot find food because of bad weather, the young may go for several hours, and sometimes for a day or more, with nothing to eat. This is most unusual for small birds. In wet weather small insect-eating birds such as flycatchers and swallows can often find insects under trees, but the swift has such long, thin wings that, good flier though it is, it cannot maneuver in these enclosed spaces. Nor does it alight to feed. Thus the young swift has evolved several remarkable adaptations to help it withstand starvation.

The nestlings of the songbirds that have been studied thus far increase steadily in weight as they get older. If food is short, which it rarely is, the young die after a few hours. The young swift, on the other hand, is adapted to withstand the loss of a large proportion of its body weight. Where the weight curve for a young songbird shows a smooth and steady increase, the curve for a young swift increases regularly only if the weather stays clear. In England the curve for the swift is interrupted by sharp drops, each of which corresponds to a spell of bad weather. At such times the bird uses up stores of fat. It also conserves its resources for the most vital functions. A young songbird usually grows feathers at the same rate however much food it receives, so that each nestling is capable of flight on the same day. If for any reason food is somewhat scarce, the nestlings leave the nest fully equipped but underweight. Conversely the growth of feathers on the young swift is greatly retarded when food is short. As a result the length of time between the hatching of a swift and its departure from the nest varies from only five weeks when food is abundant to as much as eight weeks when it is scarce.

The young swift has another unusual adaptation. A nestling songbird must keep warm to survive. Hence before it has grown feathers it is brooded by one of its parents, while afterward it maintains its own temperature control. Since both parent swifts may have to hunt all day, their naked young are able to survive long periods without warmth. But even after young swifts have grown feathers and acquired temperature control, they can lose it again when food is scarce. They revert to a "cold-blooded" state, thus conserving their resources for the vital functions. Only two other kinds of birds are known to lose their temperature control without harm: hummingbirds during cool nights and the California poorwill during hibernation.

Eventually the young swift is ready to leave the nest. A few hours after dawn, following some preliminary hesitations, it tips gently out of the hole and flies away. The parents do not know it has gone until they return with a final, and now unnecessary, meal. From the first the fledgling is completely independent of its parents, and it never returns to the nest. Although it has never before seen the world (except downwards through the small entrance to the nest) it must immediately find all its own food. It is almost certain that it simultaneously starts on its migration to Africa.

But not all young swifts survive to leave the nest. Some die of starvation, particularly during bad summers. One of the fundamental problems that interested us was why not only swifts but also other species of birds lay eggs in a clutch of characteristic size. The swift usually lays either two or three eggs a season. Presumably it is disadvantageous for it to lay more, and in fact we were able to show that two or three eggs resulted in the most efficient family size. Our combined figures showed that only 16 per cent of the young from broods of two died (usually of starvation), whereas as many as 42 per cent from broods of three died. As a result the average number of young raised by each pair was 1.7, whether they started with two or three. It seems clear that the swift cannot normally raise more than two or three young per season and that its clutch size has been adapted by natural selection to this state of affairs. In good summers the most efficient brood size proved to be three; in bad summers it was two.

As far as we know adult swifts cannot, like their young, lose their temperature control to conserve their resources. But when the weather is very cold for a long time, they have the remarkable habit of alighting on walls in groups and clinging tightly together. In this manner they keep warm like bees in their hives during the winter. More often, however, swifts respond to adverse feeding conditions by moving elsewhere. During a heavy rain, when there are no insects in the air, the birds that are near their nesting holes come in for shelter, while the others fly away from the storm and do not return until it has passed. While we watched swift nests from the outside we were sometimes drenched by passing storms, but soon afterward we saw swifts returning with their feathers quite dry.

Sometimes their flight to avoid bad weather is an extraordinarily long one. In the middle of the breeding season on the east coast of England we have seen several hundred swifts arrive from the east, apparently having crossed at least 100 miles of sea. In Scandinavia similar flights sometimes involve thousands of birds. A Finnish worker has shown that these movements occur during the passage of cold fronts, and that the birds avoid the rain by flying against the wind. This is an effective way to get out of an area of low barometric pressure. It is supposed that such midsummer move-

PARENT, its throat bulging with the insects it has gathered, returns to the nest an hour after the last fledgling has left it.

ments involve yearling birds, because swifts do not breed until they are two years old and at that time the parents cannot leave their young. This view is supported by the fact that a swift banded as a nestling at Oxford one year was recovered the following summer in the Danish province of Jutland, 550 miles to the northeast. Presumably it was on a weather movement at the time.

Although the yearling swifts do not breed, they frequent the colonies during the breeding season, selecting holes, forming pairs and even building nests. They have another habit which is perhaps the most remarkable of all those observed in the swift. Just before dark on clear, still evenings swifts collect in flocks near the colonies and gradually ascend in circles, screaming as they rise, until finally they vanish from sight. Only the yearlings do this, and they do not come back to their holes that night. Because swifts have been seen descending from great height soon after dawn, it is assumed that they spent the night in the air. It is also recorded that during the First World War an airplane pilot flew through a flock of swifts at night. This habit is unique among birds. Why swifts have it is unknown, but one wonders whether suitable roosting places are scarce in their African winter quarters, and whether there they regularly spend the night on the wing.

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THE SLOW DEATH OF A CITY

What are the forces that destroyed the well-built cities of antiquity? Curiously the most effective of them were social. An account based on the ruins of Roman Minturnae

by Jotham Johnson

Pompeii was buried on August 24, A.D. 79, by a tremendous fall of dry, hot ashes from Mount Vesuvius. Nearly all the inhabitants escaped; hardly any bodies have been found in the city other than those of slaves left chained to the doorposts.

A few days later, when the smoke had lifted, the refugees returned and burrowed in the still-warm ash, carrying off what they could find of their most precious possessions. There was talk of cleaning away the ashes and building a more splendid Pompeii, but nothing came of it, and in a little while the site was forgotten. The city lay slumbering undisturbed until modern times, when, caught like a fly in amber, it was resurrected as a museum of Roman life.

But for every city that perished suddenly there were scores which died a wasting, lingering death, living on their stored-up fat until even that was gone and there was nothing to do but stop breathing. It is the normal expectation of archaeologists to work in this kind of ruin rather than the other. I propose briefly to describe the slow processes of re-use, depletion and decay by which the materials of a city were made to serve its survivors until final exhaustion overtook both, and what happened to the city when it was no longer loved and wanted.

The cadaver on the dissecting table is Minturnae, once a bustling provincial city on the Tyrrhenian Sea 100 miles southeast of Rome. What we know about its history was uncovered some years

FOUNDATIONS alone remain of the east wing of the huge colonnade about the forum of Minturnae. These supported columns which held up the roof. All the columns except the single section on the farthest base in the center row were removed for later buildings.

ago by an expedition from the University of Pennsylvania Museum.

The time is A.D. 500. Minturnae had once had 100,000 inhabitants, perhaps 20 temples, dozens of street shrines, a series of public squares radiating from the ancient forum, paved streets, raised sidewalks, an aqueduct, an extensive system of piped spring water, public fountains, several large public baths, drains, sewers, a theater, an amphitheater, a library, forests of statues, residential areas for the rich and poor—all enclosed in a stout fortress wall with towers, gates and sentries.

In the year 500 that day has passed. Wars, invasions, brigands, pirates, long-continued economic insecurity, the entertainments and relatively greater safety offered by the capital city of Rome—all have drained off the population until no more than 15,000 to 20,000 remain.

Whole blocks of houses stand vacant. When fire starts, two or three houses or a whole block may go before it burns out. This causes little suffering; wherever one looks there is a house without tenants, and the victims take up their bundles and move in. If the new house has no front door, nearby is a door which can be cut down to fit, or a door can be knocked together out of old boards. What to do about fallen plaster is up to the individual householder; if he is concerned with appearances, he will call in plasterers, who will gouge deeply into whatever old surface remains in order to get a foothold for the new.

From time to time earthquakes, or the crowbars of some passing raider, or the probing fingers of time, sever the aqueduct. At first this is regarded as a calamity: the aqueduct is carefully repaired and restored to use. But one day it is wrecked so badly that the inhabitants shrug their shoulders and abandon it. There is little distress; a few more give up the unequal struggle and move away, and what use is the luxury of daily cleanliness in a place from which gaiety has fled? Those who stay dig wells and cisterns, build troughs and basins to catch the drip from buildings still intact, or fetch water by pail from the muddy river.

When building materials are needed, they are sought at second hand. The baths, and other buildings which no longer serve any public purpose, become quarries for roof tiles, cut stone, brick, drainpipes, metal grillwork, lumber and hardware. Lime for mortar and plaster can be had by burning limestone in a kiln. Into fresh masonry go broken roof tiles, pieces of the enormous storage jars called dolia, bricks from abandoned buildings, fragments of stone bearing inscriptions and reliefs.

As long as the existence of the citizens and their property depends on the city walls, they are carefully repaired whenever they are breached. Any heavy squared blocks of stone that come to hand will do: statue bases, pedestals, altars, wall blocks, thresholds and lintels of deserted buildings. Later, when the machinery for moving heavy stones wears out, the walls will be repaired with brick or rubble masonry.

Here a sculptor, commissioned by the community to portray a benefactor but without access to virgin marble, takes as his raw material the statue of an earlier dignitary. Into it he chisels the new likeness.

Under every street is a sewer, made carefully out of stone masonry or brick by men who understood both sanitation and the art of building for centuries to come. When from erosion or neglect a section of its vaulting falls, the paving of the street above follows it into the hole. The channel is blocked, but now no one seeks to clear it. The pit is leveled off with rubble from the nearest ruin, and two or three sidewalk slabs take the place of the basalt blocks of the original paving. For what traffic is left, sidewalks are a useless luxury. The sewer is stopped up for keeps; each householder now digs his own cesspool, perhaps, in stolid unconcern for the consequences, adjacent to his neighbor's well.

Drainage is forgotten; the rains stand in great puddles which eventually soak into the hard ground. Malaria, long latent, is on the increase. The inhabitants are not directly aware of the sinister connection, but Minturnae is beginning to get the reputation of being an unhealthy place to live.

With the spread of the ascetic phase of Christianity, the remains of the dead are no longer granted sumptuous burial in the pagan cemeteries outside the walls. Moreover, wood is too precious to be spared for coffins. A shallow grave is dug in the floor of an abandoned portico, or behind the theater, and lined with old roof tiles; the shrouded corpse is laid in that, and covered with a stone slab ripped from a wall.

In every house was once a library of papyrus scrolls: the experience of man frozen in the impersonal script of slave copyists. But nowadays to be read in Roman history, to be versed in the classics of the older literature, carries no prestige, and the rolls are put to practical purposes. Their blank sides are use-

APPIAN GATE of Minturnae gave forth on the great road to Rome. At the left is the end of the aqueduct which stopped at the gate. In the foreground lie paving blocks from the Appian Way. The gap in left center shows where fortification blocks were pulled out.

SQUARE TOWER of the city's walls rose from these three courses of subsoil foundations which remain. All the rest of the blocks were carried off over the centuries to build the medieval city of Minturno, which survives upon a hill two miles from Minturnae's ruins.

ful for accounts, receipts, letters and random memoranda. A whole scroll will get the hearth fire started on a rainy day.

Schools have ceased to meet, since only in the hope of commercial or social advancement can the child be brought to endure, or the parents to enforce, the exactions of schooling. Alone in its grandeur, and hardly touched by time or the elements, stands the most elegant of the pagan temples, maintained and carefully guarded as the local abode of the new supreme goddess: the Virgin Mary.

Another century passes, and with it new disasters and new movements of troops. Minturnae is now completely deserted, the people gone, some to refuge in the distant hills, most to the huddled safety of shattered Rome. Grass springs up in the cracks of the mortar, in the crevices between paving slabs, wherever a bit of dust has lodged in a corner. The little rootlets hold more dirt, and presently the seeds of figs and briars lodge and germinate. The vigor of their growth, driving bricks and slabs asunder, hurries the spread of ruin.

Shepherds lead their flocks through the vacant streets. With makeshift gates the open courts form adequate pens, and beneath a broken vault the shepherd finds shelter for himself and his dog. Some wood will have escaped time and conflagrations; rafters, doors, broken furniture and the branches and gnarled roots of trees will serve to warm the shepherd's lonely watch.

In this mild climate frost is not an agent of destruction, but here and there the torrential rains undermine a wall and it collapses into the street. The church of Mary, gutted by fire, stands roofless and abandoned.

Another century. The scene has changed again. On a hilltop two miles inland—easily defended and safe from pirate raids, out of reach of the bad airs of the swampy lowlands—refugees have built a new church to their patron goddess. Around it cluster a few houses, standing close together for warmth and protection. Other families come to this haven, and new construction begins.

Now the ruins of the lifeless city have new value. The city wall, a perimeter two miles long, will not be needed again, but of its 400,000 large squared stones most are still in place. These are now pried out; they furnish ready-cut stone for building the houses of the new city on the hill. The limestone paving slabs of the forum, worn smooth by the sandaled feet of 20 generations, are broken from their beds and carried off to floor the church, and to pave the little piazza that is to be the open market of the new town.

If any columns have chanced to survive unbroken, they are carted off to form an entrance porch for the church. Marble colonnettes and carved moldings are carefully removed to build a pulpit or an altar. The limestone seats of the theater, too irregular in shape to be used in their original form and too expensive to recut, find their way into the limekiln.

Lime is in ever greater demand; as activity quickens, it is used in the mortar of brick and rubble walls, then to plaster the church, then in the residences of the prosperous, then in the houses of humble folk. To get lime, first the loose fragments of marble and limestone from broken statues and shattered architectural members are burned. When this source is exhausted, builders break up statues, smash pedestals and rip out seats, benches, thresholds, well curbs and the thin flooring of temples for the limekilns' insatiable throats.

Sarcophagi of stone in the now unrespected tomb chambers are carried out into the daylight and put to new purposes. They become catchments for spring water or rain, drinking troughs for the stock, tubs for washing clothes and vats for such processes as steeping, tanning and dyeing. Some thrifty householder may be pleased to sweep out the ancient bones and bury in their place the remains of a member of his family. He defaces the original epitaph and scrawls one of his own.

As the new Minturnae grows, even the concrete core of the city in the plain is quarried. The supply of cut stones has finally been exhausted, but the fortifications of the hill city and the castle of its baron are only begun. Bricks, jagged stones and fragments of roof tiles and dolia, forming the walls of buildings in the dead city, are broken out of their sockets of mortar and hauled in cartloads to the hilltop. To obtain bricks and mortar even the villas dotting the countryside, and the arches of the empty aqueduct, are laid under contribution.

With the extinction of industry in iron, the more easily worked bronze has come back into its own for housewares, weapons, ornaments and coinage. Those bronze statues and other decorations which somehow escaped being carried off or melted down in an earlier age are now eagerly sought for their metal. In the hope of finding scrap bronze and copper for his crucible, a special kind of antiquarian picks and hacks his way through tumbled vaults and shattered walls. To get at the little iron clamps which hold stones together, whole buildings are laboriously pulled apart.

Lead is also in demand: the water conduits, long since dry and choked with dirt, are followed and ripped up. The dowels which once held the statues of the great on their pedestals are melted out to obtain the metal of the dowels themselves and the morsels of lead which soldered them in.

The debris of fallen roofs is pawed over again for roof tiles which have chanced to reach the ground unbroken, and these are used to form the sides of graves, the pans of open drains and the lining of crude tanks. Here is a slab of blue marble which was once a carved panel in the theater; it lies face down, a cross dug crudely in its back. Beneath it is a medieval grave.

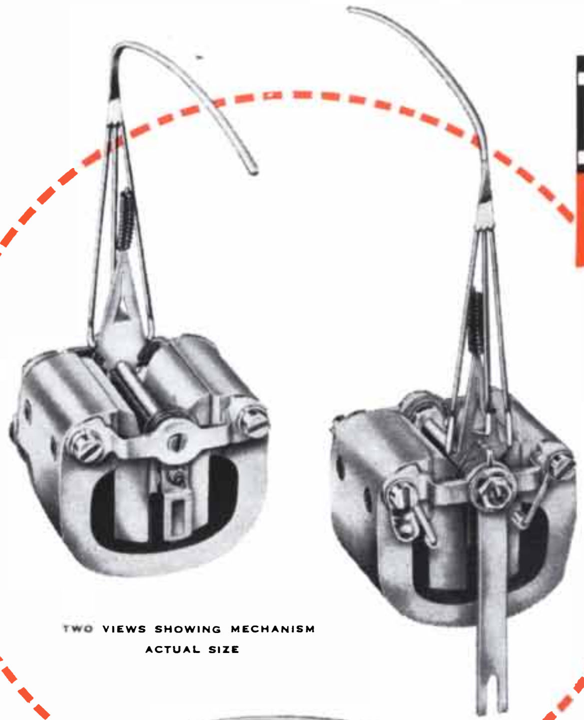
Virtually everything is used and used again. In all the 200 acres of ancient Minturnae there remain untouched only those few items for which the shepherds and medieval burghers have not yet found a need: the concrete vaults of the amphitheater, the basalt paving blocks, the stumps of columns and the fragments of architectural decoration in stones—serpentine, porphyry, granite—which cannot be reduced to lime in the kiln. Also unused are the unending carpets of mosaic.

Before the tortured corpse is left alone still further indignities are in store for it. The coming of ostentation in church decoration means that the old baths, temples and forums will be ransacked again. This time the broken columns of porphyry and granite are carefully gathered up to be sawed crosswise into thin disks. The thin slabs of rare stone from the floors and walls of temples and law courts, if any have survived previous depredations, will be carefully loosened and lifted up; scraps of molding and wainscot will be pried away. All will be carried off to adorn the churches, not only of the new town on the hill but also of Rome itself.

As the healing mantle of earth moves over the derelict, farmers plant squash and beans and the open spaces grow green with artichokes. The pointed tips of plows scar the buried walls.

With the industrial revolution and the surge in transportation, contractors will violate the basalt roadbeds of the second century to provide crushed rock for the hard roads of the 20th. Steam shovels will bite into the ancient deposits to obtain fill for bridge approaches.

Only then is the site of Minturnae ready for the archaeologist and his spade.



TWO VIEWS SHOWING MECHANISM
ACTUAL SIZE

marion
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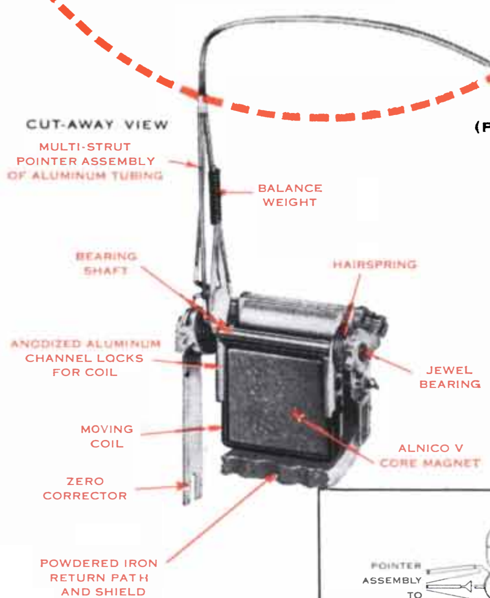
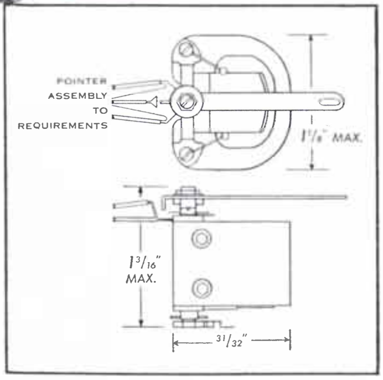
POWERFUL MOVING COIL MECHANISM HAS GYRO-LIKE STABILITY

(PATENTS PENDING)



The Marion Type MEP-1 meter mechanism was designed to develop highest possible torque for a given volume of magnetic material. Its high torque, heavy eddy current damping and low relative inertia provide unusual performance characteristics simulating the stability of a gyro, in like environment. Already it is setting new and higher standards for reliability in moving coil indicating mechanism design for aircraft application, where the influence of vibration and rapid attitude changes on pointer indication are significant factors.

The gyro-like stability of the MEP-1 mechanism results from its unique mechanical design. An end-pivoted coil assembly, with a one piece bearing shaft and precise mechanical assembly operates in a self-shielded magnet structure which produces approximately 6000 Gauss in a single air gap. When the end-pivoted moving coil, of long turning radius, operates in a magnetic field of such strength, substantial gains in torque and eddy current damping are realized. This great torque, combined with relatively light weight, permits unit bearing loadings substantially lower (i. e. larger pivot and jewel radii) than heretofore normal.



MECHANISMS BY MARION

Although developed expressly for application in aircraft navigational instruments, many of the MEP-1 characteristics make it desirable for use as the sensitive element in control devices where it is required to initiate a control function. It is one of a number of Mechanisms by Marion that extend the field of moving coil mechanism application where previously size, weight or performance characteristics prevented their use.

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Joseph Henry

In his lifetime he was famous as a scientific administrator; today he is also known as a great scientist. He discovered induction before Faraday and radio waves long before Hertz

by Mitchell Wilson

In the spring of 1837 a small group of men in an English laboratory attempted an impromptu experiment: they had rigged up an electric circuit to carry a very feeble current, and they were trying to draw sparks by closing and opening the circuit. Charles Wheatstone touched together the two pieces of wire that completed the circuit. He drew no spark. Michael Faraday said that Wheatstone was going about it in the wrong way. Faraday made a few adjustments and tried his hand. Still no spark.

A visiting American waited patiently while the two famous "electricians" argued back and forth over the probable cause of failure. As the American listened, he absently coiled a length of wire about his finger in a tight corkscrew. After a few minutes, he remarked that, whenever the two gentlemen were ready, he would gladly show them how to draw the spark. Faraday gave him one of his usual brusque answers, but the American went ahead. He added his little coil to one of the leads, and this time, when he opened the circuit, he drew sparks that were clearly visible.

Faraday clapped his hands with delight and said, "Hurrah for the Yankee experiment! What in the world did you do?"

If Joseph Henry had had Faraday's temper, he might have blurted out, "If you would only read what I publish, and understand what you read, you'd know what you just saw!" Instead the Princeton professor patiently explained the phenomenon of self-induction to the man whom the world had already credited with the discovery of induction.

There was a century and a quarter of time and a world of knowledge between the electrical experiments of Benjamin Franklin and the electromagnetic theory of James Clerk Maxwell. Much of that knowledge was gathered by one man—Joseph Henry. The time required was only 15 years—1829 to 1844. Yet Henry was a stranger in his own time. His friends mistook his scientific idealism for lack of the American spirit; international science ignored him because he was an American. Not until after he was dead and the contemporaries of his youth were gone did younger men realize that he had been a giant and that the considerable fame he had achieved during the latter half of his life had been for the least of his works. In the end science paid him its greatest tribute by raising him on the pedestal of the lower case: to the electrical units the ampere, the volt, the ohm and the farad was added the henry, the unit of inductance.

During the 25 years before Henry's appearance in science, Alessandro Volta showed how to produce a steady current of electricity, G. S. Ohm found the law that governs the strength of the current and Hans Oersted and Dominique Arago discovered that a current of electricity could create magnetism. Now, in the 1820s, a few clear-headed investigators were pondering the question: If electricity created magnetism, did magnetism in turn create electricity? Joseph Henry, a mathematics teacher in a country school in a provincial town in an undeveloped nation, not only found the answer, but went far beyond his predecessors in the depth of his research.

In Henry's background there was nothing to indicate either the extent of his ability or the direction his interest would take. He was born in 1797 near Albany and was raised in poverty. Farm hand and storekeeper's apprentice, he was a dreamy boy who barely knew how to read. When he was 13 his main concern was his pet rabbit. One day the rabbit ran away and Henry pursued it by tunneling into a church. He came up inside a locked room which contained a library of romantic novels. He forgot the rabbit and read the books.

He was so enraptured by their melodrama that the next year, when he was sent to Albany to earn a living, the 14-year-old boy made a beeline for the Green Street Theater, where John Bernard was directing his famous company. For two years Joseph Henry was a hard-working, talented apprentice actor.

In his 16th year he made his second great discovery. Confined to his room by illness one day, he happened to pick up a book left by a fellow boarder. Even late in life he could still recall the opening paragraph: "You throw a stone or shoot an arrow into the air, why does it not go forward in a line with the direction you gave it? On the contrary, why does flame or smoke always mount upwards although no force is used to send them in that direction?" Joseph Henry had found the world of science.

Henry was never able to make minor decisions. Once he ordered a pair of shoes and from day to day changed his mind as to whether he wanted square or round toes. The exasperated cobbler made the shoes both ways—one was round-toed, the other square-toed. But Henry made important decisions on the

FORMAL PORTRAIT of Henry was made during the years when he was secretary of the Smithsonian Institution by the famous photographer Mathew Brady. The negative from which this reproduction was made is in the collection of Frederick Hill Meserve.

spur of the moment. With no background, training or tradition he had decided to go on the stage. Now, with even less reason, he abruptly made up his mind to become a natural philosopher.

Henry walked to the Albany Academy and presented himself as a student. The other boys were years younger and the sons of wealthy families, but Henry lived in a private world where everything seemed possible. Fortunately he had so much talent that the real world took the shape of his private dream.

In seven months of night classes and special tutoring he acquired enough learning to get himself an appointment as a country schoolmaster. In this way he could afford to go on with his studies. Teaching and attending classes at the Academy took more than 16 hours a day, but Henry was in love with his life. Later he gave up teaching and talked his professor of chemistry into making him his assistant to set up experiments for public lectures. Henry's theatrical training had taught him that every demonstration must be foolproof, convincing and as dramatic as possible. This experience contributed to the speed and simplicity which later characterized his own experiments.

When Henry had completed his course at the Academy, he took a job as a surveyor and engineer on the Erie Canal. The days of his poverty seemed ended, and the future was wide open. A man of his training could make a fortune almost anywhere from the seaports of the East to the distant hills of Wisconsin. After a few months, however, he was offered the professorship of mathematics and natural philosophy back in Albany. He felt the country needed advanced teachers even more desperately than engineers. Reluctantly he accepted the post.

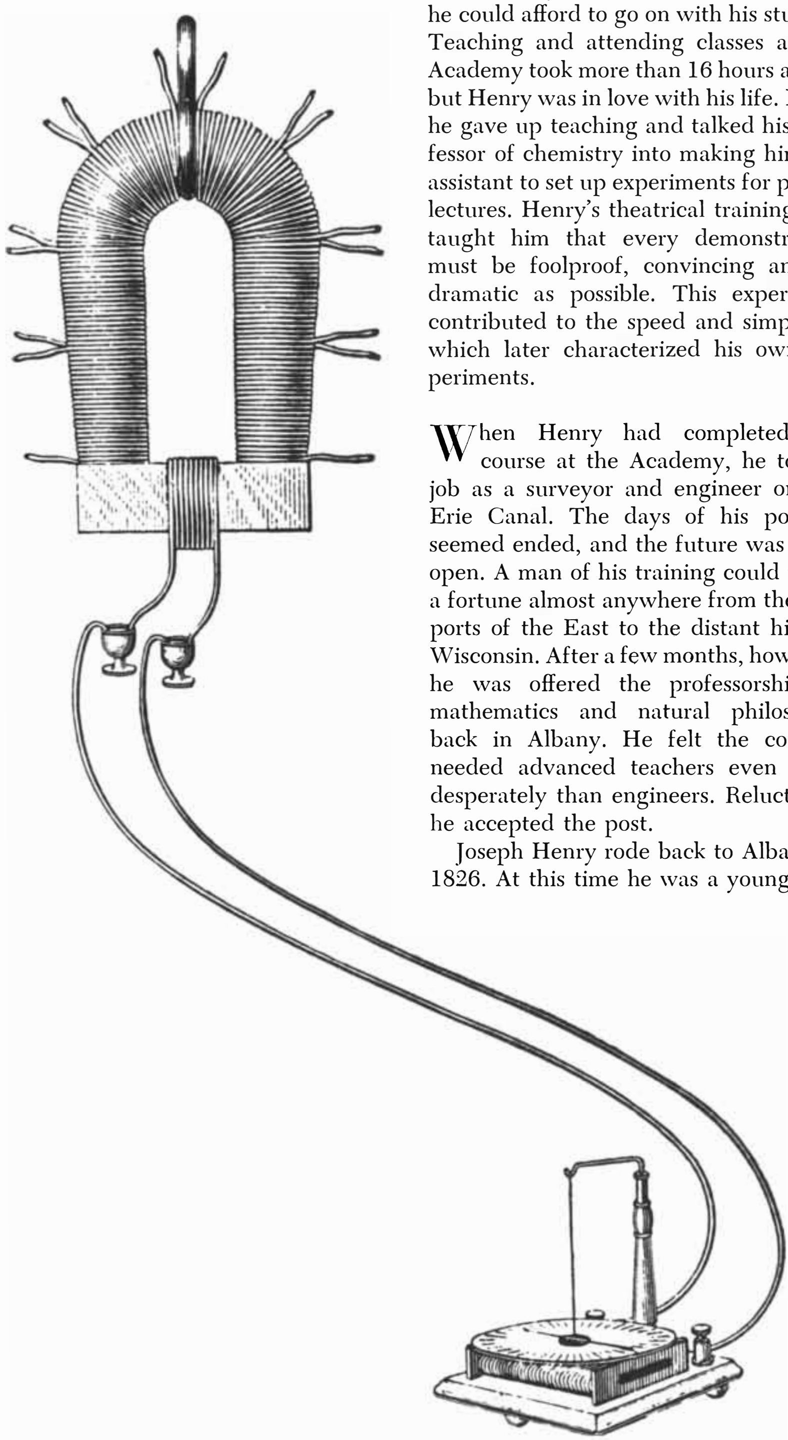
Joseph Henry rode back to Albany in 1826. At this time he was a young man of striking appearance: he had curly blond hair, piercing blue eyes and the carriage of an actor. Behind the facade was the basic gift of great investigators—the instinct for reducing ideas to their essential simplicity.

His teaching schedule was heavy; the only time he could steal for research was the summer vacation, when he was permitted to convert one of the classrooms into a laboratory. At the end of August his apparatus was stored away and the benches and desks were returned.

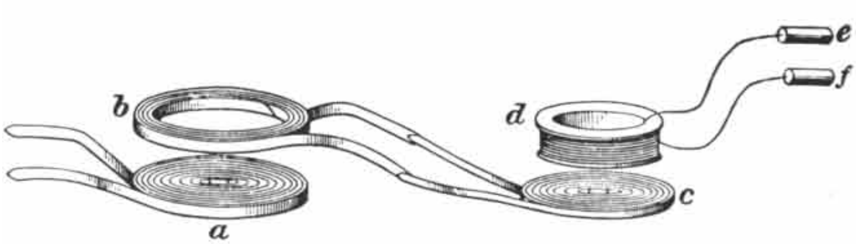
His first work was to build electromagnets along the lines described by William Sturgeon of England. Sturgeon's magnet was a bar of iron coated with shellac, around which was loosely wrapped a length of bare wire. Sturgeon bent his bar into the form of a horseshoe; seven pounds of metal could be lifted into the air when he turned the current on, and just as dramatically dropped when he turned the current off. One summer in the Albany schoolroom Henry built a magnet that could lift one ton. Instead of insulating the iron, Henry had carefully insulated the wire. This allowed him to wrap the wire as closely as he wished, so that he could pack an enormous number of turns along the iron bar. Henry described his device in the *American Journal of Science*, published by Benjamin Silliman of Yale.

The experiments on electromagnets led Henry to the problem of generating electricity from magnetism. All the previous investigators, misled by the fact that a steady electric current induced a steady magnetic field, had sought some arrangement by which a steady magnetic field would induce an electric current. The usual test was to wind a length of wire around a piece of magnetized iron, to rub the free ends of the wire together and to look for sparks. Henry's great achievement was to perceive that the answer lay not in a steady magnetic field, but in a magnetic field that was changing.

In the crucial experiment Henry used one of his horseshoe-shaped electromagnets with a straight piece of soft iron, which he called an armature, running between its poles. Around the armature he wound a length of insulated copper wire about 30 feet long and connected its ends to a galvanometer some 40 feet away. Thus he had two coils completely independent of each other, the magnet coil attached to a battery and the other coil only to the galvanometer. He was ready to begin. "I stationed myself near the galvanometer," he wrote later, "and directed an assistant at a given word to . . . connect the . . . battery attached



EARLY EXPERIMENT by Henry first made electricity from magnetism. At the top of this illustration is a horseshoe magnet wound with wire. Across its poles is an armature also wound with wire. When Henry turned the magnet current on, a magnetic field was set up in the armature. This induced a current in the armature coil, and the needle of the galvanometer moved. When the current was turned off, the needle swung the other way.



TRANSFORMER principle was described in an early paper by Henry. A coil of flat copper strip (*a*) was connected to a battery. When the current was interrupted, a current was induced in a second coil (*b*). If this coil was connected to a third coil (*c*), a current could also be induced in a fourth coil (*d*). By holding a pair of electrodes (*e* and *f*) in his hands, Henry was able to gauge how much the coils stepped up or stepped down the voltage.

to the magnet." Then the miracle happened. "The north end of the galvanometer needle was deflected 30 degrees, indicating a current of electricity in the wire surrounding the armature."

An instant later Henry must have been disappointed. Even though the current continued to flow through the magnet coil, the needle returned to its zero position. He signaled his assistant to turn the current off. To his amazement the moment the circuit was broken the needle moved again, but in a direction opposite that of the first swing.

Henry soon guessed the reason for this unexpected behavior. It was only while the magnetism in the armature was changing—from zero to its full value as the magnetic circuit was closed, from full value back to zero as the circuit was opened—that anything happened in the secondary coil. He summed up the effect as he understood it in this way: "An instantaneous current in one or the other direction accompanies any change in the magnetic intensity of the iron."

Henry had now established that a current will be induced in any wire in a changing field. He shortly discovered that "any wire" includes the very wire that created the field in the first place. As early as 1829 he had observed the magnetic effect of a current on itself—now called self-induction. It was by making use of this phenomenon that he later confounded Faraday and Wheatstone.

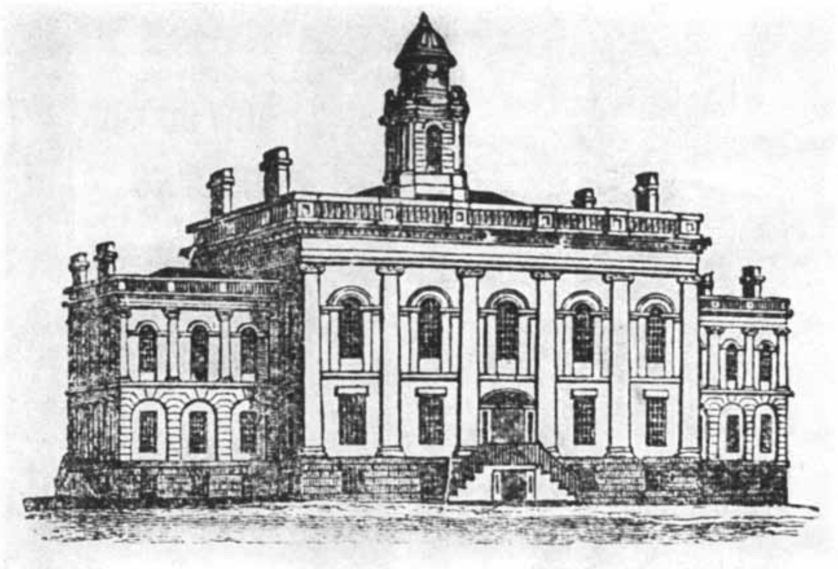
Now this great work, and much more, was done in consecutive summers before 1831; but the first account of it, from which the foregoing quotations are taken, was tragically not written until 1832. Henry knew that he was working on the most difficult problem of his day; he knew that he had solved it before anyone else. But he had never had any personal contact with science as a profession, and the European scientists whose names he knew seemed figures of towering stature. He was therefore reluctant to publish any of his results until he could accumulate an overwhelming mass of data. His modesty was actually the unconscious pride of genius demanding to be accepted on its own terms. In addition, he was terribly pressed for time. There was not a moment to spare for the laborious work of composition.

For the rest of his life he was to regret that he had not publicized his results. "I ought to have published earlier," he said sadly. "I ought to have published, but I had so little time! It was so hard to get things done! I wanted to get out my results in good form, and how could I know that another on the other side of the Atlantic was busy with the same thing?"

The blow fell in May, 1832. Still filled with the confidence that he was years ahead of the world on a great work, he casually picked up a British journal. He read two paragraphs and the magazine slowly fell from his hands: he was years ahead of nobody. Faraday had just reported his independent discovery of electromagnetic induction.

Faraday's 1832 paper was based on results achieved as recently as the previous autumn. Although Henry had been years ahead of Faraday, he now felt that there was no point in publishing his own results at all. He was sick with despair. However, Silliman had heard of Henry's work and continually pressed him to describe it for the *American Journal of Science*. Henry finally sat down and began the series of papers that was to secure his place in history, but only after his death.

Not since the scientific work of Benjamin Franklin had there been such a chance for American science to achieve world distinction. The young Republic was particularly sensitive to the European attitude that America had nothing culturally to offer. Instead of sympathizing with Henry, many of his friends blamed him for having failed to publish in time. They called him "irresponsible" and "unpatriotic." There were a few who understood. Instead of punishing him,



ALBANY ACADEMY was where Henry acquired most of his education. In seven months he was able to learn enough to become a country schoolmaster and continue his studies.

they increased his opportunities for research by getting him an appointment to the faculty at Princeton.

While still at Albany, Henry had invented the electrical relay. He used it to create the first electromagnetic telegraph system, anticipating Samuel F. B. Morse by at least five years. Henry's signaling device was a bell. He never published the details of the relay as a separate paper. He lectured on its practical importance, but to him it was merely an adaptation of the much deeper principles he had already propounded. He explained the device to Morse and to Wheatstone, the inventor of the English telegraph, and both men used it freely.

Henry's relay was a horseshoe magnet wound with the wire of the long telegraphic sending circuit. Across the pole pieces of the horseshoe was a movable iron armature, which was pulled toward the magnet each time a current impulse of the signal arrived. As the armature moved up and down it mechanically opened and closed a second circuit which contained its own battery. The second circuit contained either a printing mechanism or the horseshoe coil of still another relay so that the strengthened signal could be sent on again. Except for mechanical details Henry's relay has gone unchanged.

At Princeton he built an enlarged telegraphic device and sent signals over a mile of wire, stating that successive relays would allow him to continue the circuit indefinitely. He continued his researches on induction, achieving a remarkable understanding of the details of the phenomenon. In one page he described what was in effect the principle of the electric transformer: "The apparatus used in the experiment consists of a number of flat coils of copper ribbon. . . . Coil No. 1 was arranged to receive the current from a small battery, and coil No. 2 placed on this, with a glass interposed to insure perfect insulation; as often as the circuit of No. 1 was interrupted, a powerful secondary current was induced in No. 2. . . . The shock, however, from this coil is very feeble, and scarcely can be felt above the fingers." In other words, the current had been increased, but the voltage had been stepped down. "Coil No. 1 remaining as before, a longer coil was substituted for No. 2. With this arrangement the magnetizing power was much less, but the shocks were more powerful." Now he had cut down the current, but stepped up the voltage.

Henry's contemporaries knew so little about electricity and electric circuits that they could find in his work only what they were equipped to understand. To those who read the *American Journal of Science*—and its circulation was extremely small—Henry had simply improved the electromagnet. His fundamental insight into the transformer was entirely missed, and therefore forgotten within a few years. Very few Europeans bothered to read the *American Journal.* A decade after the publication of Henry's original papers they were reprinted in England, but even then they were only superficially appreciated.

Henry rarely used mathematics in his analysis of physical phenomena. In his time Ohm's law—today taught to high-school students—had not yet been reduced to quantitative terms. Henry's analysis was powerful, but it was qualitative rather than quantitative. Voltages were given a relative measurement by the intensity of the shock felt by the experimenter; current intensities were similarly measured either by chemical means or, when they were very weak, by the acid taste produced in the experimenter's mouth. Henry detected feeble voltages by the shock to his tongue. But even though he dealt only with relative quantities, he was able to arrive at the correct exponential shape of the growth-and-decay curve for current in an inductive circuit.

Henry made his last great contribution to the study of electricity in 1842. In that year he demonstrated the transmission of radio waves. It was half a century before the celebrated experiments of Heinrich Hertz. Henry noticed that the effect of a spark could be detected by a parallel circuit 30 feet away. Spark coils operating on the second floor of his laboratory building magnetized needles in the basement, the induction taking place through 30 feet of air and two layers of 14-inch flooring. The following excerpt from his paper shows he clearly understood that this was a wave phenomenon, and that it was identical with the propagation of light: "It would appear that the transfer of a single spark is sufficient to disturb perceptibly the electricity of space throughout at least a cube of 400,000 feet of capacity; and when it is considered that . . . the spark is [oscillatory] . . . it may be further inferred that the diffusion of motion in this case is almost comparable with that of a spark from a flint and steel in the case of light."

In 1846 Henry's career as a research worker came to an end. The U. S. Government was seeking a director for the newly founded Smithsonian Institution, and Henry was offered the post. To accept meant that all his time would be devoted to administrative duties. But Henry felt that here was a great opportunity to give American science a cohesive form. Twenty years earlier a sense of duty had caused him to give up a profitable career in engineering. Now he felt it was his duty to give up research in order to act as the first national administrator of science.

By the time Henry was in his fifties, he was considered one of America's leading scientists. But his contemporaries knew him as a scientific administrator: director of the Smithsonian, adviser on science to Abraham Lincoln during the Civil War, the man to whom young inventors like Morse and Alexander Graham Bell went for encouragement. They did not know him as the scientific worker whose 15 years of electromagnetic research was far ahead of its time.

Henry's work as director of the Smithsonian touched many fields. He set up a project to report information about the weather, which later developed into the U. S. Weather Bureau. He persuaded James Lick to found his famous observatory in California. He served on innumerable government advisory boards, including the commission that in the 1850s examined the plans for an ironclad gunboat for the U. S. Navy. Henry was the only commissioner to recommend the design. His advice was disregarded, and, when the Civil War broke out, the design was adopted by the Confederacy in the building of the *Merrimac.*

The meteorological data which Henry collected for the Smithsonian was gathered by telegraph from 500 observers throughout the country east of the Mississippi River. As each telegraphic report came in from a local area, a small round card was pinned in position on a large map of the country. Different colors indicated rain, snow, clear weather or cloudiness. Henry said that storms moved eastward at the rate of 20 to 30 miles per hour, and he successfully taught the usefulness of the weather map to farmers, railroad people and shipping interests.

Henry was the first man to study the relative temperature of sunspots. In 1848 he projected an image of the sun on a white screen. Using a very small thermopile he was able to measure the relative temperature of each point on the projected image. He discovered that the images of the spots were cooler than the areas around them.

The development of the dynamo in the last decade of Henry's life marked the beginning of the use of alternating current. Only then were men able to go back and appreciate the importance of Henry's work. Maxwell's electromagnetic theory of the 1860s pointed up, in retrospect, Henry's statement that the propagation of electricity through space was identical with that of light. Hertz's experiments enabled investigators to look back and understand that Henry himself had been transmitting signals of spark frequency and receiving them on crudely tuned circuits. Henry received full honors only after his death because it took 40 years for men to know enough to appreciate what he had done.

Parentage and Blood Groups

Blood tests are now widely accepted as evidence in cases where parentage is disputed. An account of the principles that underlie the inheritance of the various blood types

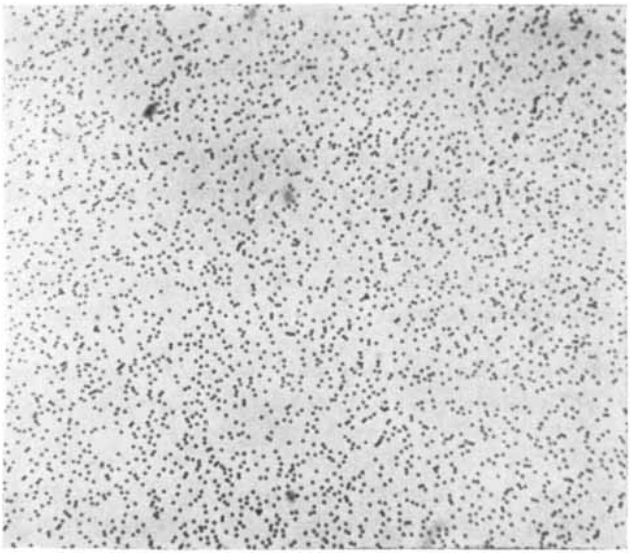
by Alexander S. Wiener

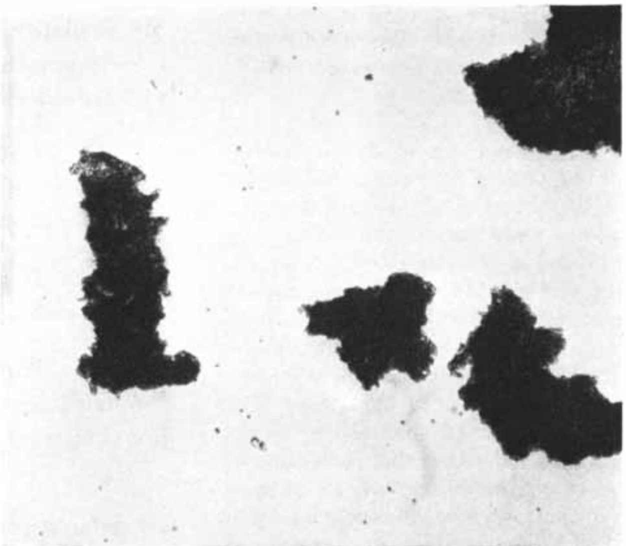
It was not so long ago that the use of blood-grouping tests in cases of disputed parentage was greeted with skepticism. Today the evidence of blood tests is routinely accepted in the courts of New York City, and many states have passed statutes empowering their courts to order such tests whenever parentage is disputed. Blood tests are also used to solve other legal problems. For example, they can assist in determining whether bloodstains came from one person or from another.

The difficulty of establishing paternity has been recognized from the earliest Biblical times. According to the Talmud no man may swear that he is the father of a child; only the woman may swear that she is the mother. With the rise of modern genetics it became clear that problems of disputed parentage could be solved by applying the Mendelian laws of heredity. Unfortunately there are few human traits which have a simple hereditary mechanism. Although such individual traits as hair color, eye color, body build, head shape and facial features are determined by heredity, so many genetic and environmental factors are involved that the resemblance of such traits is notoriously unreliable as a means of determining parentage. The blood group of an individual, on the other hand, is inherited precisely by a relatively simple mechanism. It can be determined at birth, and it remains unchanged throughout life.

It should be emphasized, however, that blood tests can be used only as negative proof; that is, they can *disprove* paternity or maternity, but they cannot *prove* them. A brief account of the heredity of blood groups will explain this limitation.

As everyone knows, blood consists largely of cells suspended in plasma. Most of the cells are the disk-shaped red cells, which give blood its color. When blood is shed, the plasma protein fibrinogen is converted into fibrin, forming a fine network which enmeshes the red cells and forms a blood clot. This clotting or coagulation must be distinguished from agglutination or clumping, which is the basis of blood-grouping tests. After blood coagulates, the clot contracts and squeezes out the clear straw-colored fluid called serum. Thus serum contains all the ingredients of plasma except fibrinogen. The most important constituents of both plasma and serum are the proteins albumin and globulin. In response to infection or to the injection of a foreign substance the body produces antibodies, which are a modified form of serum globulin. These



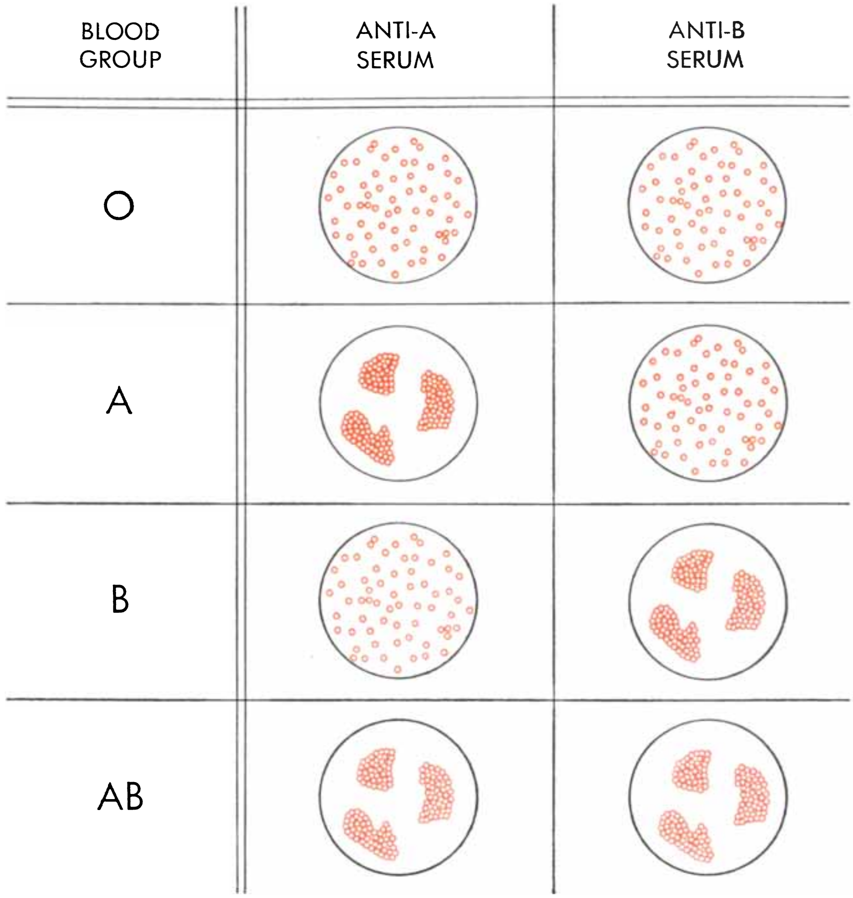


RED BLOOD CELLS from an individual of a certain blood group are evenly suspended when placed in saline solution (*left*). When serum from an individual in one of certain other groups is added to the suspension, clumping or agglutination takes place (*right*).

antibodies have the remarkable property of reacting specifically with the foreign substances that elicited their production.

In addition to the immune antibodies which protect the body against disease, there are so-called natural antibodies which occur spontaneously in normal blood plasma. Among these are the blood-group antibodies. By the end of the 19th century it had been shown that blood cells from different animal species differ chemically even when they look the same under the microscope. For example, rabbits injected with sheep blood produce a powerful antibody capable of destroying sheep blood cells but not blood cells from a species unrelated to sheep. Moreover, it was found that the serum of one animal species normally contains antibodies which clump or dissolve blood cells from other animal species; this explains why transfusions of blood between animals of different species may cause death. Searching for individual differences in human blood, the famous pathologist Karl Landsteiner mixed serum from normal individuals with the red cells of other normal individuals. He found that when the serum and blood cells of certain individuals were mixed, the red cells clumped together; and, when the serum and red cells of other individuals were mixed, there was no clumping. By means of these reactions Landsteiner showed that human beings could be divided into blood groups. This discovery not only made possible safe blood transfusions, but also led to the development of the important modern sciences of immunogenetics and immunohematology. For this discovery and other pioneering work in immunochemistry Landsteiner received the Nobel prize in 1930.

Landsteiner showed that the naturally occurring blood-group antibodies were of two major types which he designated as anti-A and anti-B. On the surface of the red cell there are two corresponding substances called agglutinogens; because their exact chemical nature is unknown they have been named A and B. If serum containing anti-A is mixed with a suspension of blood cells bearing agglutinogen A, the cells will clump together in large masses that will be visible to the naked eye as brick-red granules. On the other hand, if anti-A is mixed with B blood cells, or anti-B with A blood cells, there is no reaction: the cells remain suspended without clumping. This simple principle is the basis for all blood-group tests, including



TYPING of blood according to its groups is done by taking the unknown blood and mixing it with anti-A serum and anti-B serum respectively. The characteristic reaction of blood of the four groups is indicated by the depiction of evenly suspended and agglutinated red cells.

those for more recently discovered blood types.

The properties A and B can occur in four combinations, which give rise to the four well-known blood groups: O, A, B and AB. By injecting rabbits with human red cells Landsteiner and Philip Levine later discovered other agglutinogens, of which the most important are called M and N. These two agglutinogens determine only three blood types: M, N and MN. M-N types are not important in blood transfusion because anti-M and anti-N are rarely present in human serum. But since the M-N types have a simple mechanism of heredity, they are of considerable value in problems of disputed parentage. Every individual must belong to one of the three M-N types as well as to one of the four A-B-O groups. Thus for each individual there are three times four, or 12, possible combinations of these blood groups.

The more recent work on blood grouping has revealed the existence of numerous additional agglutinogens in human blood cells, notably the system including the Rh factor. These Rh-Hr factors sometimes cause dangerous reactions in blood transfusion, and an incompatibility of the factors between mother and fetus may give rise to a serious blood disease in the newborn baby. Here, however, we are concerned with the hereditary aspects of the Rh-Hr types. It happens that there are at least four different kinds of Rh factors and at least two reciprocally related Hr factors, so that this blood system comprises numerous blood types. Still other blood-group systems—the P, the K-k, the F, the Le, the Lu and so on—have recently been discovered, so we can now distinguish thousands of different types of human blood. This suggests that some day it may be possible to identify an individual by his blood type just as reliably as by his fingerprints.

The heredity of blood groups of course rests on the same Mendelian principles that govern the inheritance of other traits. The units of heredity—the genes—occur in pairs, one member of each pair being contributed by the father and the other by the mother. When the egg or sperm cells are produced, the members of each gene pair separate so that each cell contains only a single gene of each kind. Then, when the sperm fertilizes the egg, the genes are paired again in the offspring.

The M-N types provide one of the clearest examples of Mendelian inheritance in man. The agglutinogen M is determined by the gene *M*, while the agglutinogen N is determined by the gene *N*. Thus only three combinations of the genes are possible: *MM*, *NN* and *MN*. These combinations correspond to the three blood types M, N and MN. Obviously when individuals of type M intermarry, their sperm and egg cells bear only gene *M*, and all their offspring will have blood of type M. Parents of type N similarly "breed true." On the other hand, if type M and type N individuals intermarry, all their children must be type MN. Parents M × MN will have children half of whom are type M and half type MN, and similarly the children of the mating N × MN will be half N and half MN. Finally in the mating MN × MN the children will be 25 per cent M, 25 per cent N and 50 per cent MN.

The M-N tests can be used to exclude paternity in the following way. Suppose that the mother has blood of type N, the child of type MN and the supposed father of type N. Obviously the man in question is not the father, because the child has the agglutinogen M which is lacking from the blood of both the mother and the supposed father. On the other hand, if the man had belonged to type M or MN he would not have been excluded. Neither would he have been proven the father. Any other man belonging to either of these two types could have been involved. That is why blood tests can be used only in the negative sense to disprove paternity and not to prove it. The chances that an accused man will be exonerated by M-N tests are about one in six. When the accused man is given the benefit of tests for the three systems A-B-O, M-N and Rh-Hr, he has better than an even chance of being exonerated if he is not the father.

The same tests can be applied in cases where parents suspect that their baby was exchanged with another in the hospital. Here the chances of a successful identification are much greater because there are two babies and two sets of parents. Indeed, almost all such problems can now be solved.

The heredity of the four A-B-O blood groups is slightly more complicated than that of the M-N types. Here it is necessary to postulate the existence of at least three genes: *A*, *B* and *O*. These correspond to agglutinogen A, agglutinogen B and the agglutinogen in group O blood cells. (Group O cells are characterized not merely by the absence of A and B, but by a special agglutinogen O for which there is a corresponding serum anti-O. Anti-O sera are rare and those which have been found give only weak reactions, so that in practice group O is diagnosed by the absence of any reaction with anti-A and anti-B.) The three genes form six possible pairs: *OO*, *AA*, *AO*, *BB*, *BO* and *AB*. Persons with the genes *OO* will have blood of group O; those with the genes *AA* or *AO* will have group A blood; those with the genes *BB* or *BO*, group B blood; those with the genes *AB*, group AB blood. Note that individuals of group A or group B can have a mixed pair of genes (*AO* or *BO*) or an unmixed pair (*AA* or *BB*). In cases of disputed parentage it is always assumed that group A or group B parents have mixed genes (*AO* or *BO*). This is to allow for the widest variety of possible blood types in the offspring.

If we make this assumption, there are only four gene pairs in the A-B-O group involved in cases of disputed parentage: *OO*, *AO*, *BO* and *AB*. There are in turn only 10 possible matings among these pairs: $OO \times OO$, $OO \times AO$, $OO \times BO$, $OO \times AB$, $AO \times AO$, $AO \times BO$, $AO \times AB$, $BO \times BO$, $BO \times AB$ and $AB \times AB$. The reader can work out the results of each mating on the basis of the principles given for the M-N group.

When we deal with the Rh-Hr group the situation is much more complex. To account for the 18 "standard" Rh-Hr types it is necessary to postulate eight genes, which may be combined in 36 pairs. Indeed, when all the known Rh-Hr factors are taken into account, 16 or more genes must be postulated.

These principles may be further illustrated by actual cases of disputed parentage. In Case 1 a man was accused of being the father of a child born out of wedlock. Blood tests showed the following:

	A-B-O	M-N	Rh-Hr
Putative father	A	N	Rh_1Rh_1
Mother	O	N	rh″
Child	B	MN	rh

It is evident that the tests provide triple proof that the accused man is not the father of the child. First, the child possesses the agglutinogen B but its mother does not. Thus the father of the child must belong to group B or AB, and the accused man is excluded. Second, the child has the agglutinogen M, which is absent from the blood of both the mother and the accused man. Third, because the accused man belongs to type Rh_1Rh_1 every one of his children must inherit at least one of these Rh factors from him, while the child in question is Rh negative.

Needless to say the man was acquitted of the charge. Had only one of the three tests excluded him, this would have been sufficient. At the same time the case demonstrates why it is never possible to solve all such problems with blood tests. There is always the chance that the accused man will have the incriminating blood type whether he is guilty or not. This is true no matter how many different blood types are discovered. For example, if one blood test excludes 50 per cent of falsely accused men, and if another test also excludes 50 per cent, the two tests combined will not exclude 100 per cent of the men but only 75 per cent. In 25 per cent of the instances the evidence of the two tests will coincide.

In Case 2 the results were as follows:

	A-B-O	M-N	Rh-Hr
Putative father	AB	M	Rh_1Rh_1
Mother	A	M-N	rh
Child	B	MN	Rh_1Rh

Here the accused man is not excluded. This does not necessarily mean that he is the father of the child, because there are many other men with this combination of types or other combinations of types which are compatible with that of the child. Therefore the results of these tests must be disregarded and the decision based on other evidence.

In Case 3 it was suspected that two babies had been exchanged in a hospital. Blood-grouping tests on the parents and the babies showed the following:

	A-B-O
Mr. X	O
Mrs. X	O
Baby No. 1	A
Mr. Y	AB
Mrs. Y	O
Baby No. 2	O

It is apparent that baby No. 1 is not the child of Mr. and Mrs. X; nor is baby No. 2 the child of Mr. and Mrs. Y. If the babies are interchanged, the blood groups correspond, and that is what the court decided.

FX-104

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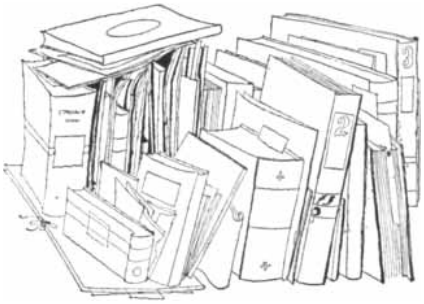


BOOKS

A physicist examines the dilemmas of science in terms of the questions asked by the Greeks

by James R. Newman

NATURE AND THE GREEKS, by Erwin Schrödinger. Cambridge University Press ($2.00).

Erwin Schrödinger is a master in the art of writing small books on large themes. In the 91 pages of *What Is Life?* he presented a bold and exciting synthesis of facts and theories in physics, chemistry and biology; an ingenious explanation of how living organisms perpetuate themselves and thwart entropy; and a moving epilogue on the philosophical implications of his scientific model. A few years later in the 67 pages of *Science and Humanism* he depicted with freshness and imagination the relation between quantum physics and ethics. In *Nature and the Greeks,* the latest of his little books, he continues his search for a comprehensive philosophical vision—a vision based on science yet affording a more rounded and satisfying picture than is comprised in the sum total of scientific knowledge. What is common to these essays is the attempt to define man's place in the universe and to alleviate—so far as a philosopher can hope to achieve this object—the widely shared, deep-felt anxiety of living in a world about which we seem to understand less as we learn more. *Nature and the Greeks* carries Schrödinger's special mark: a wholeness of outlook resembling that of the ancient philosophers to whom he now turns for refreshment, insight and the wisdom of innocence.

Schrödinger characterizes his "plunge" into ancient thought as a trend of the times, not confined to classical scholars and not to be explained as mere escape from the dismal present. Several factors impel the student of ideas to look backward for clarification. Among them are the unresolved conflict between science and religion, the conspicuous failure of science to shed light on certain questions of profound human concern, the "inordinately critical situation" in which nearly all the fundamental sciences now find themselves. Perhaps, says Schrödinger, if we can trace today's confused "scientific world-picture" to the earliest stage of Western philosophy we may gain an understanding not only of how we got into this mess but how we can get out of it.

Our intellectual and emotional plight is sharply reflected in the relations between science and religion. The historic conflict between these two modes of thought has been from time to time suspended in a truce but never settled in a treaty of peace. This mutual and abiding distrust is deep-rooted and does not spring from "those well-known irrelevant details from which it ostensibly issued," such as the controversies over the theories of Galileo and Darwin. The true cause is the fundamental antagonism of two metaphysical attitudes. It is important to be clear on this point because the loose phrase "conflict between science and religion" tends to obscure the true nature of the controversy. Science does not so much conflict with religion as compete with it for power. The faith known as scientific naturalism presents as its witnesses the discoveries of science; religion appeals for support to what the British logician H. H. Price calls a "sense of the Divine" and "otherworldly beliefs." In this competition each side has learned not to underestimate the persuasiveness of the other's arguments. Religion has reason to fear that, if the scientific outlook prevails, God will become no more than a "gratuitous embellishment" to our image of the world. Science, on the other hand, has no gifts to match the spiritual comforts and consolations offered by religion. It may have been possible for an educated man of the 18th century to be content with the image science had created of the universe—a complete, dependable, well-ordered affair. This image has been destroyed and its successors do not comfort us.

Even ardent disciples of the scientific outlook would not claim that it so completely fulfills the "innate longing for a religious or philosophical stabilization, in the face of the vicissitudes of everyday life," as to make one feel "quite happy without anything more." It is a precept of scientific method that one must not look for final answers. It is part of the scientist's discipline to put up with gaps in his knowledge, indeed to emphasize rather than conceal them lest specious conjectures discourage the search for true answers. Religion, however, cannot thrive in the twilight of tentative beliefs. Religion's answers must be final, the religious picture whole and self-contained.

In view of this fundamental divergence, it is not surprising that science and religion have not been reconciled. The front is quiet today, but not because the antagonists have composed their differences. Instead they simply ignore each other. "It is pathetically amusing to observe how on the one side only scientific information is taken seriously, while the other side ranges science among man's worldly activities, whose findings are less momentous and have, as a matter of course, to give way when at variance with the superior insight gained in a different fashion, by pure thought or by revelation." While the great majority of educated people in Western society are adherents of scientific naturalism and have rejected the religious outlook, it cannot be denied that in many instances these views are held with misgivings. Many, says Schrödinger, are undecided which outlook to adopt, and are saddened by the spectacle of a divided, antagonistic search for the same object—a fuller understanding of man and his place in nature. And in our period, so threatened and so bleak, the craving is more desperate than ever for even "a vague hope that the 'world' or 'life' of experience be embedded in a context of higher, if as yet inscrutable, significance."

This, then, is one of the major circumstances exciting renewed interest in ancient thought. Among the Greeks the "wall separating the two paths, that of the heart and that of pure reason" did not exist. Learned men were expected to have opinions, and to express them, on all subjects. It was not regarded a virtue to speak about atoms and to be silent about the soul, to propose theories about the motion of the planets and to disregard theories of ethics. Essentially there was only one subject; whatever was discovered about any part of it would bear on every other part.

The crisis of the fundamental sciences—which is the result, as Alfred North Whitehead once remarked, of scientific theory outrunning common sense—has also contributed to the present "retrospective tendency." The old, secure, orthodox assumptions as to space and time have been overthrown. The relativistic theory of gravitation seems to show "that the distinction between 'actor' and 'stage' is not expedient." Absolute motionlessness, absolute simultaneity, the non-interchangeability of energy and matter all now repose in the dustbin of discarded concepts. The ultimate constituents of matter are thought to be hybrids and are sometimes called wavicles—either because we cannot decide whether they behave like particles or waves or because we think they themselves cannot decide. The final touch of caprice is introduced by quantum theory in challenging what was always regarded as the most obvious and fundamental property of a particle, namely, its individual identifiability. It is now asserted that only when a corpuscle is moving "with sufficient speed in a region not too crowded with corpuscles of the same kind does its identity remain (nearly) unambiguous; otherwise it becomes blurred."

It should be emphasized that these paradoxes do not belong exclusively to one sphere of thought. They are bred on ground common to science and metaphysics. Measuring instruments do not, after all, give information meaningful in itself; the canons of interpretation, the assumptions underlying the research procedure, determine the inferences drawn from the measurements. This is further evidence to support Schrödinger's thesis as to the unity of scientific and philosophic thought and the need for a comprehensive reappraisal of our scheme of things. In this reappraisal the study of Greek philosophy may help us to unearth "obliterated wisdom" and discover "inveterate error" at the source. "By the serious attempt to put ourselves back into the intellectual situation of the ancient thinkers, far less experienced as regards the actual behavior of nature, but also very often much less biased, we may regain from them their freedom of thought—albeit possibly in order to use it, aided by our superior knowledge of facts, for correcting early mistakes of theirs that may still be baffling us."

One of the prominent questions occupying the ancients concerned the reliability of the senses. That they often deceive us must have been evident even to primitive man. A straight stick obliquely immersed in water looks broken; honey tastes bitter to the jaundiced—a favorite example in antiquity of sensory delusion and relativism. "But the reliability of the senses is only the preamble to much deeper questions, which are very much alive today and of which some of the ancient thinkers were fully aware. Is our attempted world picture based on sense perceptions alone? What role does reason play in its construction? Does it perhaps ultimately and truly rest upon pure reason alone?" Until recently scientists scorned the attempt to explain the outside world by pure reason. But in the last two decades several of the foremost natural philosophers, including Sir Arthur Eddington and E. A. Milne, have from a handful of postulates and by mathematical reasoning alone deduced certain remarkably ingenious models of the cosmos. The most spectacular and dramatic instance was Eddington's inference that there are exactly $16 \times 17 \times 2^{256}$ elementary particles in the universe. Even Einstein's general theory of relativity, though based on and confirmed by experimental evidence, could only have been discovered, Schrödinger suggests, by a person with strong confidence in the inner harmony, simplicity, beauty and "reasonableness" of nature. One can perceive a similar faith underlying some of the grand unifying hypotheses of science—entropy, conservation of mass and energy, least action and so on.

The philosophical opinions of ancient times covered the full range: from unqualified *a priori* interpretations of the universe to the most radical forms of empiricism. Bertrand Russell once remarked that the Greeks were not addicted to moderation either in their theories or in their practice. Though they knew very little about the workings of nature they were not diffident in formulating universal laws; nor did individual philosophers refrain from denouncing as charlatans other philosophers with whom they disagreed. Schrödinger points out that despite our vastly superior knowledge the controversy is as heated as ever, and it is even doubtful that present-day philosophers, though mindful of the libel laws, are any more hospitable to the opinions of their opponents than were the Greeks.

Parmenides of Elea, who flourished

about 480 B.C., gained fame for his extreme "antisensualism." His doctrine, set forth in a poem "On Nature," held that the senses deceive us consistently, that the multitude of sensible things is an illusion, that there is in fact only One Thing and that since this One Thing is everywhere there is no change, no empty space, no motion. Parmenides' philosophy was "the purest monism" ever constructed. His favorite pupil Zeno bequeathed to posterity a group of fascinating little puzzles involving Achilles, a tortoise and an arrow, which company he enlisted to prove that motion is impossible. Some of the best philosophers have tried to refute his arguments, but none of the refutations are convincing. The majority of persons continue to believe that things move.

The other extreme of opinion is represented by Protagoras, a Sophist philosopher of the fifth century B.C. To him is ascribed the saying "Man is the measure of all things." Schrödinger describes Protagoras as the "outstanding example of pure sensualism," a judgment which I believe to be misleading. Protagoras was a skeptic: he had as little confidence in the dependability of the senses as in the existence of objective truth of any kind. The fact that he doubted man's ability to fathom the structure of reality by pure reasoning does not imply that he advocated faith in the senses. Despite his skepticism Protagoras had pragmatic leanings. He was led from the doctrine that one man's opinion is as good as another's to the advocacy of a more equitable social system in which the majority would rule and "human institutions would be adapted to suit changing human requirements." Protagoras was probably a fine fellow but I think his philosophy has little bearing on Schrödinger's inquiry.

More to the point are the teachings in the sixth century B.C. of the philosopher Pythagoras and his school. We derive from them the conception of an external world "revealed to the intellect but not to the senses." Russell has said that Pythagoras was "one of the most important men that ever lived, both when he was wise and when he was unwise." He has been described as a combination of Albert Einstein and Mary Baker Eddy. He believed in the migration of the soul and he preached against the sinfulness of eating beans, of looking into a mirror beside a light and of sitting on a quart measure. His thigh was reputed to be of pure gold. His pupils so revered him that they did not dare to pronounce his name and were wont to settle doctrinal arguments by the crushing phrase, "The Master said so." The Pythagorean order made a fetish of secrecy with respect to their mathematical discoveries as well as their religious tenets. A great scandal is said to have occurred when Hippasos, a faithless disciple, divulged the existence of the pentagon-dodecahedron; for this offense he was of course expelled from the order and "his grave was prepared for him as for a defunct."

It is hard to extract the truth about Pythagoras from the mixture of fact and legend, especially since he left no writings. Yet some of his doctrines are pretty well authenticated, and either he or his disciples are known to have made important mathematical discoveries. Pythagoras said that "all things are number," a celebrated dictum which I shall certainly not try to explain. Schrödinger suggests it originated as "a sweeping generalization of truly imposing boldness and grandeur, from Pythagoras' famous discovery of the integral or rational subdivisions (for instance, ½, ⅔, ¾) of a [musical] string." This connection between music and arithmetic survives in the mathematical terms "harmonic mean" and "harmonic progression." Other mathematical advances registered by the Pythagoreans include the great theorem about right-angled triangles, proof of the existence of incommensurables, and many propositions of number theory which are systematized in Euclid's *Elements*.

Further evidence for the combination of mysticism and scientific reasoning of the Pythagorean school may be found in its cosmology. The Pythagoreans knew that the earth was a sphere; Schrödinger says they were probably the first to know it. They taught that the earth was a planet which rotated and revolved (in the same period) about a fixed center (a "central fire," but not the sun) and that the observed diurnal motion shared by all the celestial bodies was not real but apparent. There are mistakes in this cosmology, but there are also astonishing insights, and one must admire the feat of "self-liberation from the prejudice that man and his abode needs must be in the center of the universe."

The Pythagoreans originated the religious attitude toward mathematics. This has been responsible for many mischievous preconceptions, and has addled men's minds in other ways, but it has also been immensely useful. The fruitful search for order, symmetry and regularity in nature has been stimulated by Pythagorean convictions. Mystical doctrines as to the supremacy of numbers have played a central part in the creative activities of some of the foremost mathematicians of history. In general "the intimate blending of religion and reasoning, of moral aspiration with logical admiration of what is timeless," which comes from Pythagoras, has profoundly influenced philosophical thought from Plato through Descartes, Spinoza and Kant.

Under the name of the Milesian School (a name derived from the city of Miletus in Asia Minor) are grouped the Ionian philosophers of the sixth century B.C.: Thales, Anaximander and Anaximenes. Each had a naturalistic explanation of the world, a unified theory based not on mathematics or theology but on sense perception. Thales, who was a successful businessman as well as a philosopher, said that everything is made of water. He regarded the earth itself as a flat disk of watery essence floating on water. This is not only a more sensible hypothesis than that everything is number, but has the merit of being testable. Anaximander, though not a businessman, was a more profound philosopher, and rejected Thales' theory. He held that all things come from a single but indeterminate primal substance which is all-pervasive and eternal. One of his remarkable conjectures, based on his observation of the helplessness of newborn land animals, related to the origins of man. Anaximander thought that man had once been a fish and that, as the dry land appeared, some of the more venturesome fishes left the sea and adapted themselves to the new environment. Anaximenes suggested that air was the basic substance, and that by rarefaction and condensation "every kind of matter could be transformed into the solid, fluid or gaseous state in suitable circumstances."

It can be said that the Milesians were the first scientists. Schrödinger supports this position on two grounds. First, "the grand idea that informed these men was that the world around them was something *that could be understood*, if one only took the trouble to observe it properly: that it was not the playground of gods and ghosts and spirits who acted on the spur of the moment and more or less arbitrarily. . . ." They believed the world to be ruled by "eternal innate laws." They were curious men, eager to find out and capable of being astonished. Plato, Aristotle and Epicurus emphasize the importance of being surprised, and we recognize it as an indispensable ingredient of the scientific attitude. Second, it was a momentous step to hold that all matter, despite the infinite variety of its forms, is intrinsically the same stuff. "From our present outlook we must say that this move touched the most essential point and was amazingly adequate."

Before discussing the atomists Schrödinger deals very briefly with Xenophanes, who as a rationalist offered healthy opposition to the mysticism of the Pythagoreans, and with Heraclitus, who said profound and oracular things about the cosmic flux (*e.g.*, "You cannot step twice into the same river, for fresh waters are ever flowing in upon you.") The treatment is superficial but Schrödinger never fails to make interesting points.

In the final section of his survey Schrödinger examines the ancient atomic theory of Leucippus and Democritus. The main features of their views are (1) that the atoms are invisibly small; (2) that they are in perpetual and disorderly motion; (3) that this motion persists by itself and requires no additional force for its continuation; (4) that the atoms possess weight not as an intrinsic property but as a result of their "whirl motion"; (5) that the soul itself is composed of atoms, "particularly fine ones with particularly high mobility." It is astonishing how closely the first three of these points resemble the modern scientific outlook, and even more astonishing that Leucippus and Democritus arrived at their beliefs without a scrap of experimental evidence. How did they do it? Schrödinger is disinclined to credit the possibility that this marvelous achievement was a "lucky guess." Instead, he suggests that atomism is a "thought pattern not so exclusively based on the recently discovered evidence as the modern thinkers believe, but on the cooperation of much simpler facts, known before, and on the *a priori* structure, or at least the natural inclination, of the human intellect." The Ionian philosophers anticipated the theory that the external world consists of nothing but atoms and the void. Anaximenes' concept of rarefaction and condensation as the cause of all the apparent changes in matter is hard to understand if matter itself is a "continuous structureless jelly." On the other hand if one thinks of a physical body as composed of innumerable small particles which remain always unchanged but which arrange themselves in different shapes as they recede from each other (rarefaction) or crowd more closely together (condensation), one achieves a comprehensible and beautifully coherent picture of physical reality. The additional merit of this model is that it does not challenge the validity of geometrical statements involving concepts of continuity and the like, since physical reality is only an "imperfect realization" of mathematical ideas. As a geometer, Democritus was fully aware of the difficulties which arise when one seeks to fit the concept of the mathematical continuum into physical thought. "To him atomism was a means for bridging the gulf between the real bodies of physics and the idealized shapes of pure mathematics."

But observe how the same problem has returned to plague us. On the hypothesis that the physical world is composed of particles, which can be counted, paired off, measured and so on, the most important physical theorems have been discovered. Yet there is now serious doubt that the atomic theory is "true," that individual single particles "exist," that the model which has proved to be so immensely fruitful corresponds to the "actual objective structure of the 'real world around us.'" There is evidence that the model of a structureless jelly world, of a continuum with curves and twists and folds but without holes or granules, of a universe which the topologist but not the arithmetician can master, is a closer approximation to the actual state of things than the atomic model "conditioned by the nature of human understanding." Of course the issue cannot be regarded as settled. Schrödinger admonishes us to "preserve an extremely open mind toward the palpable proofs of the existence of individual single particles." But we are forced to admit that even as the store of our knowledge increases, our theoretical understanding of it, darkened by logical paradoxes, is "diminishing at almost the same rate." We are confronted by the same difficulty that troubled Democritus, but we are unable to accept his solution.

In his excellent study *Early Greek Philosophy* the Scottish classical scholar John Burnet characterizes science as "thinking about the world in the Greek way." Schrödinger holds this assertion to be true in two important respects. The first is the more or less obvious fact that we share the Ionian hypothesis that nature is comprehensible and that observation and reason rather than magic afford the way to understanding. It is our faith, in Whitehead's words, that at the base of things we shall not find mere arbitrary mystery. Schrödinger's second point is more interesting and represents his distinctive contribution to a deep and vexed problem of philosophy. We recognize that, in its attempt to achieve objectivity in describing and understanding Nature, science deliberately simplifies the task by requiring the observer to cut himself out of the picture to be constructed. Now this removal by the observer of his own personality seems to us not only harmless but indeed an essential part of scientific procedure, a necessary guard against bias and irrelevant intrusions. After all, if we are looking for honest weight, we must keep hands off the scale. But we cannot get off so easily in appraising the character and the consequences of this resolute act of self-elimination. For in truth cutting ourselves out of the picture leaves it woefully incomplete; our masterpiece "gives a lot of factual information, puts all our experience in a magnificently consistent order, but it is ghastly silent about all and sundry that is really near to our heart, that really matters to us. It cannot tell us a word about red and blue, bitter and sweet, physical pain and physical delight; it knows nothing of beautiful and ugly, good or bad, God and eternity."

There is still another consequence of our initial renunciation. Whenever we inadvertently try to put ourselves back into the picture—an action to which we are drawn almost irresistibly—there arise the very paradoxes that so gravely threaten the foundations of science.

Is there an escape from this dilemma? Schrödinger says no, at least not as long as we can find no substitute for the method founded by the Greeks for understanding the external world. We are not part of the universe that science constructs for us. When the scientist cuts himself out of it, he cuts us out too. In his disconcerting mechanical model there is no place for consciousness, will, endeavor, pain and pleasure; the scientific world view "contains of itself no ethical values, no aesthetical values, not a word about our ultimate scope or destination. . . ."

Science has no answer to the question "Whence came I, and whither go I?" That is the price we pay for committing ourselves to this discipline of thought, a price which some think too high. Yet others are convinced that the rewards are adequate. They share Schrödinger's faith that science represents "the level best we have been able to ascertain in the way of safe and incontrovertible knowledge." They draw strength from his conviction that any thought we achieve in the many millions of years of tenancy we may anticipate even on this globe "will not have been thought in vain."

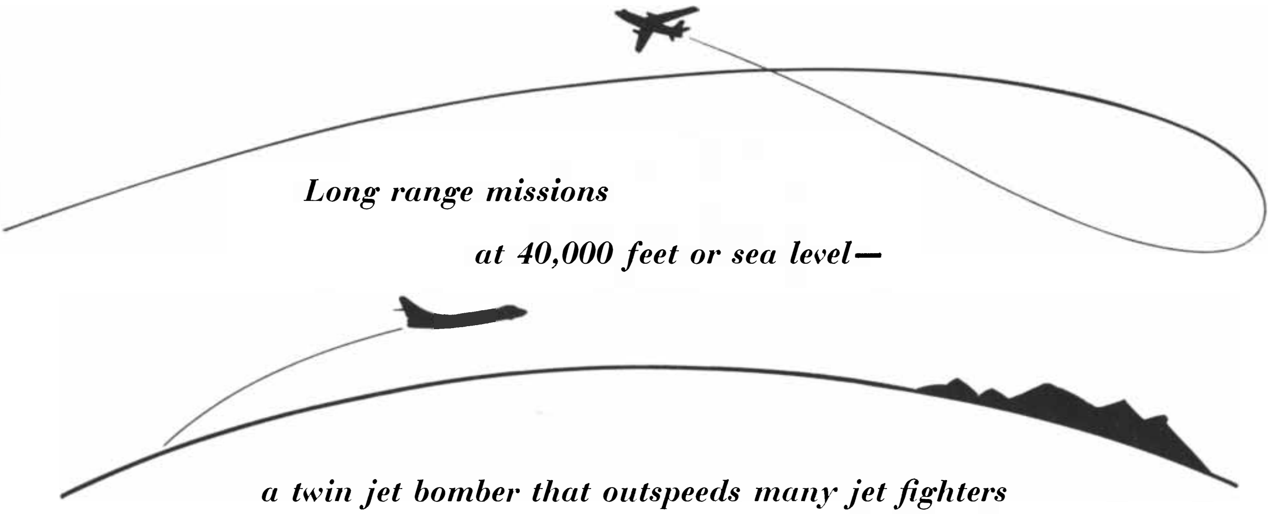
Nature and the Greeks is not as successful as the other books Schrödinger has written in the same vein. It seems to me uneven in treatment; at times forced in its comparisons and analogies, struggling to achieve clear expression where Schrödinger himself is not clear in his thought; unduly discursive, as if the side trips were more attractive to the author than the main journey. Conceding that Aristotle and Plato are not among the most original of scientific philosophers, it is surprising that Schrödinger is unwilling to allot even a few pages to a discussion of their influence on the development of science and philosophy. All the same this is a wise, a deep, even a moving and touching book. Schrödinger is never banal; he never addresses the reader in a public voice; he does not gloss over difficulties but admits us to his own uncertainties; he has a remarkable capacity for relating science to man. What one feels most of all is that he cares about men and regards their loneliness and longing for answers to social, moral and religious questions as no less within the scientists' domain than questions about genetics or wave mechanics.

Short Reviews

DIALOGUES OF ALFRED NORTH WHITEHEAD, as recorded by Lucien Price. Little, Brown and Company ($5.00). This is an unsuccessful work of piety. Lucien Price, an editorial writer for the Boston *Globe*, made the acquaintance of Alfred North Whitehead in 1932. Whitehead was then 71 years of age and had been lecturing on philosophy at Harvard since 1924. Price frequently visited Whitehead and took part in many memorable conversations at his legendary Sunday evening at-homes and on more intimate occasions. Almost from the start Price kept a record of what was said at these gatherings. We now have his assurance, supported by the fact that Whitehead had read and endorsed the book before he died, that the text is an accurate, often "verbatim" report. Whitehead's dazzling versatility is reflected in the variety of topics discussed here; they include the philosophy of mathematics, Ulysses S. Grant, Wagnerian music, Plato, Robert M. Hutchins, the Elizabethan drama, the meaning of liberty, the importance of muddleheadedness, anti-Semitism in America, Franklin D. Roosevelt, Chinese humor, and the naval strength of ancient Athens. The result is an occasionally interesting but painfully contrived book which falls short of what Price intended to accomplish and what Whitehead's superlative qualities deserve. The philosophy is fragmentary, the literary and historical judgments glib; a theatrical intellectualism pervades the whole. There are too many epigrams and they sound rehearsed. The dialogues are neither natural nor spontaneous, nor are they dialogues in any real sense. With the others present performing more or less as end men, Whitehead does most of the talking. While what he has to say is sometimes profound and sometimes witty and sometimes wise, he discourses so incessantly that it is hard to credit Price's statement that he came away after "four or five hours' lively interchange with him, exhilarated as with a raging flame of life." Price may be as worshipful as Eckermann, but Whitehead could not possibly have been as tiresome as Goethe.

JOHN STUART MILL, by Karl Britton; PEIRCE AND PRAGMATISM, by W. B. Gallie; SPINOZA, by Stuart Hampshire; JOHN LOCKE, by D. J. O'Connor; BERKELEY, by G. J. Warnock. Penguin Books (50 to 65 cents). Penguin continues to render an invaluable and a unique service to literate readers of every interest, indeed to all readers except those exclusively devoted to Westerns and science fiction. The books listed above are a representative selection of recent volumes in the series edited by Professor A. J. Ayer on foremost philosophers. Professor Britton's study is a simply written, accurate exposition of the thought of one of the leading 19th-century philosophers, who concerned himself with social problems as well as with logic. The life and thought of the most original of American philosophers, C. S. Peirce, is sympathetically and ably handled by Professor Gallie. His concise and readable book will help to introduce Peirce to an audience for whom his extensive and expensive *Collected Papers* was never intended. The doctrines of Spinoza, whom Bertrand Russell calls the "noblest and the most lovable" of the great philosophers, are appealingly set forth by Hampshire, a fellow of New College, Oxford. O'Connor has done a clear, straightforward job on the empiricist John Locke, who founded the British philosophic tradition. Bishop Berkeley's brilliant ideas, which continue to stand as sentinels of clear, vigorous thinking, are well explained by G. J. Warnock, an Oxford philosopher. It is perhaps appropriate to note that the total cost of these five fine books is $2.95, which is less than the average novel, and much less than any volume of memoirs by an admiral or politician.

SIR HANS SLOANE AND THE BRITISH MUSEUM, by G. R. de Beer. Oxford University Press ($2.90). Hans Sloane



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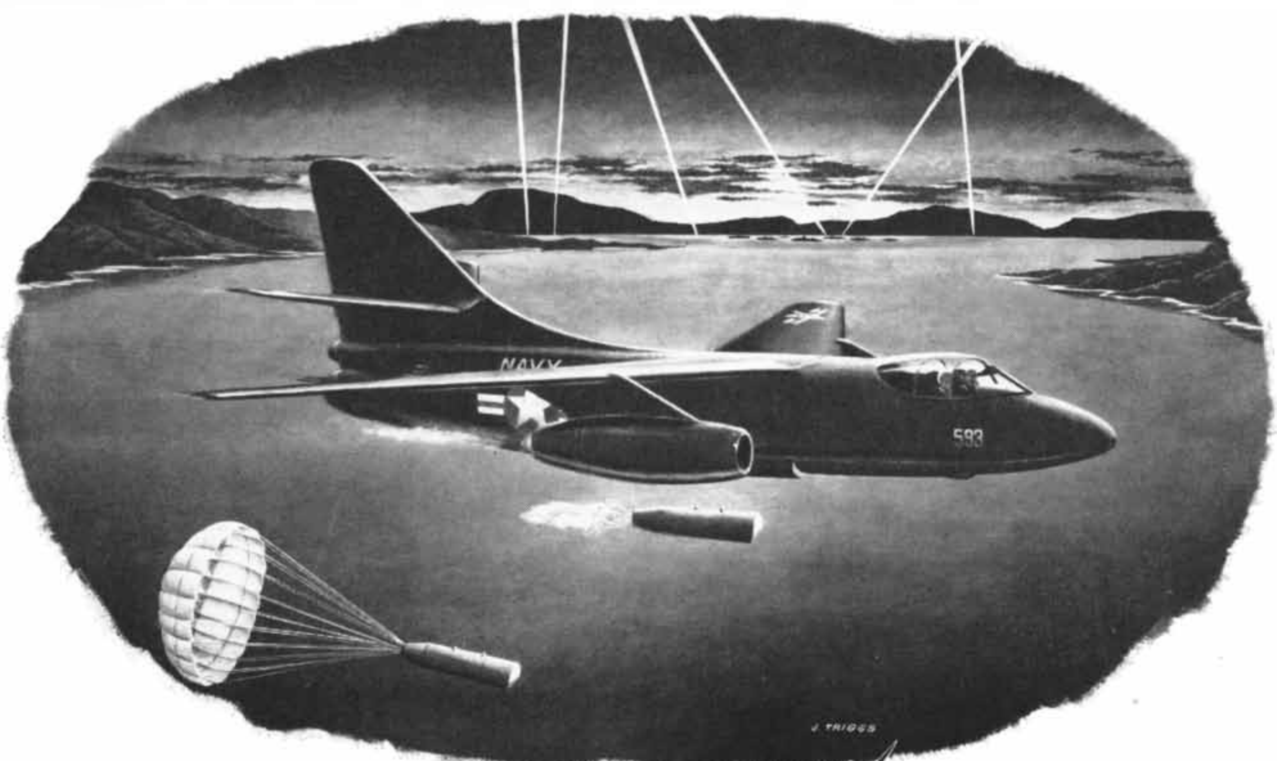

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was a British physician and naturalist who during a long life (1660-1753) and a lucrative professional career acquired an enormous collection of books, manuscripts, natural history specimens, precious stones, coins and other objects which on his death were acquired by Parliament for the nation and formed the nucleus of the British Museum. The breadth of Sloane's scientific, literary, classical and antiquarian interests is reflected in the richness and diversity of his acquisitions. He bought things and collected them not merely for the sake of possession but also because of the range of his lively mind. He took a long voyage to Jamaica, which is described in one of his works; his great circle of friends included Samuel Pepys, John Locke and Sir Christopher Wren; he contributed many papers to the Transactions of the Royal Society, and served as its president after the death of Isaac Newton. The story of Sloane's life is fully and agreeably recounted in this volume by the Director for Natural History of the British Museum.

PERSEPOLIS, VOL. I: STRUCTURES, RELIEFS, INSCRIPTIONS, by Erich F. Schmidt. University of Chicago Press ($65.00). This lavish folio volume is the first installment of a report on excavations at the site of the ancient Persian city of Persepolis. The project was initiated in 1931 by the late James Henry Breasted, and executed in the field first under the direction of the German archaeologist Ernst Herzfeld and later under Erich Schmidt, a member of the Oriental Institute of the University of Chicago. Persepolis was the capital of Persia under Darius I in the sixth century B.C. and was destroyed two centuries later by Alexander the Great. Its famous ruins and monuments include the tombs of the kings and the remains of the imposing palaces of the Achaemenid dynasty, with their magnificent 100-columned audience halls, majestic stairways and long friezes. These remarkable chronicles in stone portray royal persons and dignitaries, lions, bulls, mythical man-bulls, processions of subjects and tribute bearers, and, not least, personal attendants to the king carrying towels and "fly whisks." The many plans, sketches, folding plates and photographs of Schmidt's monograph afford a sumptuous panorama. The descriptive text gives many details of life under Xerxes, Cyrus the Great, Darius and Artaxerxes. It is necessary to point out, however, that a few of the photographs have been crudely retouched and badly reproduced.

THE ORIGINS OF EUROPEAN THOUGHT ABOUT THE BODY, THE MIND, THE SOUL, THE WORLD, TIME AND FATE, by Richard Broxton Onians. Cambridge University Press ($9.50). The second edition of a fascinating study of comparative thought in which Professor Onians examines Greek and Roman beliefs about the nature of the mind and the soul, what happens at death and after, the form and beginnings of the world, the meaning of time, the shaping of human destiny, the "significance of the body and of its various parts in men, in animals, in plants." The main labor of interpretation is concentrated on Homer, from whose writings there emerges "a strange vision, a remarkable system of beliefs, coherent in itself and, when we grasp the appearance of things strangely conspiring, not unreasonable." The author goes further and traces the fundamental ideas which for centuries determined the values and guided the behavior of the Greeks and Romans through the literature, legends, theories, customs and religions of other peoples, among them the Semites, Slavs, Norsemen, Celts and Anglo-Saxons. In profundity, wealth of learning, felicity of treatment and universality of interest this is a book in the high tradition of *The Golden Bough.*

HISTORY OF ECONOMIC ANALYSIS, by Joseph A. Schumpeter. Oxford University Press ($17.50). The noted Austrian economist Joseph Schumpeter, professor of economics at Harvard from 1932 until his death four years ago, left a huge, unfinished manuscript on which he had been working for nine years. His widow, Elizabeth Boody Schumpeter, succeeded in converting the material into a book which is a landmark of economic thought. Unfortunately she, like her husband, did not live to see its publication. Schumpeter was immensely gifted—erudite, profound, literate, sensitive to ideas in a dozen different disciplines which bear upon but lie outside the sphere of economics—and this posthumous work displays the full measure of his powers. It is a history from Greco-Roman times of "the intellectual efforts that men have made in order to *understand* economic phenomena," a spacious account of the models and theories they have created to explain economic events. Schumpeter's outlook was conservative but this does not prevent him from presenting fairly the economic systems of those with whom he disagreed or from praising the systems of those whose political beliefs were abhorrent to him.

What General Electric people are saying . . .

E. KEONJIAN

Formerly an electronics scientist in Leningrad, Mr. Keonjian is now with the Electronics Division

". . . There is considerable progress in science, particularly in applied fields, such as electronics, in Russia. There are several reasons for it.

First, the Soviet Government encourages development of applied science in every field which has any prospects of being useful for military purposes.

Second, in the atmosphere of strong political pressure and frequent "purges" in which every individual lives in Russia and in satellite countries, many people regard applied sciences as relatively "safe subjects" that often do not follow all the changes and zigzags of the Communist Party line, as in the case of social science. Consequently, more people devote themselves to applied sciences rather than to any other sciences or activities.

Third, the Soviet scientists have to study the foreign languages more intensely than we do here. They watch very closely all foreign scientific and technical developments and make more efficient use of them than we do.

Fourth, the Soviet Government has complete control over the school system in Russia. It determines their programs, number of students, and their assignments after graduation.

Fifth, unlike the Western world, the Soviet Government is able, without any limitation, to concentrate the selected manpower of the country, as well as the full effort of its technology, in few selected fields which it regards vital for increase of military potential.

There is a prevailing opinion among the Western scientists that we strongly underestimate Soviet science. With few exceptions this is, however, not true. The Western scientists should always remember that together with some real achievements, there is still a considerable amount of propaganda, outward manifestation, and even charlatanry in most of the Soviet claims in science, and the tragic disgrace of Prof. Lysenko's "achievements" in Soviet genetics is not without parallel in other sciences behind the Iron Curtain.

at the IRE, Pennsylvania Section

F. K. McCUNE

Mr. McCune is General Manager, Atomic Products Division

". . . We at General Electric believe that electric companies will be owning and operating a number of atomic power plants within the next ten years.

We believe some of these will be full-scale and, what is most important, they will operate electrically at competitive costs, possibly within five, certainly within ten, years.

We believe that this will be accomplished without Government subsidy for production plant construction or operation, and that Government-supplied fuel will be priced at cost-of-production levels.

We believe that two nuclear reactors best suited for earliest and most effective competition with conventional fuel plants in this country are (a) the light water-moderated and cooled boiling reactor, and (b) the graphite-moderated water-cooled reactor. These we think hold greatest promise in the years just ahead.

In saying these production plants will operate without Government subsidy, I do not wish to detract from the immeasurable significance of knowledge developed through A.E.C. contracts. Of course, the Government's large expenditures for research and development of plutonium production reactors, mobile power reactors, and other power reactors form the base from which private industry can proceed. But, the important thing here is that we believe production size atomic power plants can be made economic. They will stand on their own feet. They may sell products to the Government. They will certainly buy nuclear fuel from the Government. But, trading with the Government need not be a subsidy.

Atomic Industrial Forum Panel
Washington, D. C.

W. S. HILL

Mr. Hill is Manager—Technical Recruiting Services, Engineering Services Division

". . . In the matter of educating the technical graduate, what industry is trying to say to educators concerning the engineer and the scientist is this:

Give us well-rounded men.

Cultivate habits of mind that will enable them to seek out unsolved problems, to systematically explore, and where possible to add to useful knowledge.

Give them basic tools in the form of fundamental knowledge for this task, but above all show them how to acquire more tools for themselves as they reach the limits of their past training.

Encourage qualities of initiative and responsibility.

Make them aware of the economic evaluation society will inevitably put on their contributions.

Help them toward attitudes of cooperation with their associates in work and community because much of their lives will be spent in working with and for people.

Prepare them to better adjust to people, situations, and the changing complexities of our society.

Foster alertness to broad social trends and the implications these have to their field of work.

G. E. Review

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THE AMATEUR SCIENTIST

About binoculars that are out of line and a telescope built by a group of schoolboys

Conducted by Albert G. Ingalls

On May 27, 1697, William III of England granted to one "Caleb Heathcote & Others" permission to buy from its Indian owners a certain tract of "good, bad and indifferent land" situated in what is now Dutchess County in the State of New York. One portion of the tract containing "177 acres, 3 roods and 16 perches" has turned out to be amazingly productive, not of the region's traditional hay and cider, but of teen-age amateur scientists. The annual harvest now averages .125 boy per acre, give or take a rood, a yield as high as you are likely to find in any rural area of comparable size in the U. S.

The switch from farm produce to amateur scientists came in 1931, when a young educator named Edward Pulling acquired the land and established the Millbrook School for precollege boys. The property was well equipped—as a farm. Its improvements included a cottage, a barn, a smokehouse, a pigsty and assorted outbuildings—everything but a bank account. For the latter Pulling substituted what has since proved to be an equally effective resource: the enthusiasm and energy of boys. The students of the new school quickly transformed the hayloft into a gymnasium, the stallion's box stall into a science classroom and the pigsty into a place where mathematics and Latin could be taught. Today, after 23 years, the Millbrook School has a physical plant which can be compared to that of many colleges—including a battery of well-equipped laboratories featuring fine instruments also built by the students.

How do you harness boy-power and, when you do, why does the boy develop a bent for science? Writes Pulling: "We believe that, in addition to maintaining high standards of scholarship and conduct, an independent school is obligated to educate its students for intelligent and active citizenship, and this requires above all else a sense of responsibility. Instead of merely talking about the responsibilities of community service in the age of science, we confront the boys with community problems. The result is inevitable. In clearing boulders from a hillside for a much-desired ski run the boy experiences Archimedes' principles at first hand, and in carrying the job through to completion with his fellow students he gains new insight into behavior patterns that are the domain of the social sciences.

"Perhaps the most significant thing about community service at Millbrook is that it is directed by the boys themselves. Enrollment has been kept small enough so that every boy, every year, can be challenged by at least one job of major importance to the welfare of the whole school community.

"There are no 'made' jobs at Millbrook," continues Pulling. "All are real in that they contribute in one way or another to the effective functioning of the school and add meaning and interest to the life of the boys. In several cases the community jobs constitute projects which have been undertaken for the Government. For instance, a bird-banding station is operated under the auspices of the Fish and Wildlife Service; a cooperative weather station is maintained for the Weather Bureau. At the request of the National Bureau of Standards our physics department, with the aid of a group of keenly interested students, for several years operated an ionosphere propagation measurement station, the purpose of which was to collect statistics on the behavior of short-wave radio transmission.

"Some of the projects have resulted in the construction of buildings or the making of permanent equipment. For instance, our zoological committee built and now operates the zoo building and its associated outside cages. This committee is responsible for the care and feeding of all animal and bird specimens, preparing zoological exhibits, operating the experimental station in cooperation with the biology department and conducting research programs."

Nearly every mail brings to this department of Scientific American one or more letters from harassed science teachers asking for sources of inexpensive telescopes and other scientific apparatus. Chalk talks, explain the teachers, are no substitute for laboratory practice. "How," one teacher asks, "can you equip and maintain a high school laboratory on a budget of $1,000 a year, or less?" Pulling appears to have found one solution. Doubtless local circumstances will prevent its full adoption by some schools. But many of its features would appear to have universal application.

When we learned that Millbrook had recently built, at a cost to the school of less than $400, a full-scale astronomical observatory—including a rotating aluminum dome, a 12½-inch telescope and a shock-proof floor—we decided to make a personal visit and learn the secret of Pulling's methods.

We were welcomed by Neale Howard, teacher of mathematics, physics and chemistry, whose outstanding qualification for the job appears to be a boundless enthusiasm for working with boys. When we arrived Howard had been conferring with a student group interested in local climatology—some problem having to do with the dam and weir which the group has constructed to measure the runoff of the region. Howard excused himself and we headed for the observatory, which is situated away from the lights of the school on the opposite side of an artificial lake.

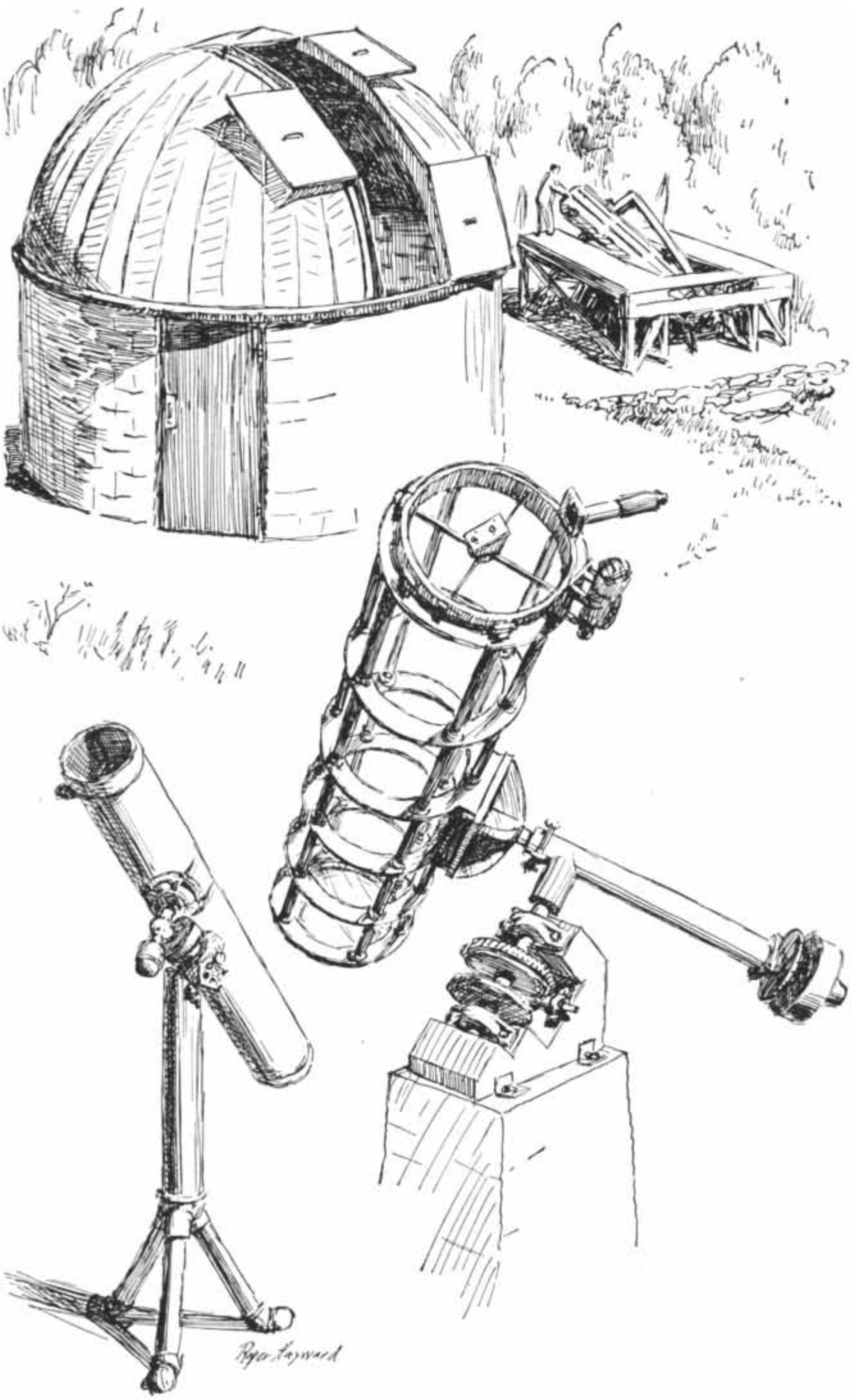
Before we had come to Millbrook, Howard had given us the background of the observatory. He wrote as follows: "I think I should explain that we have no illusions about turning out scientists here. Our job is to prepare boys for college. We try to create an atmosphere in which they find it easy to accept social responsibility. In the course of this many develop a relish for science and, incidentally, nearly all of them wind up with a scientific avocation. Some, of course, go on to professional careers in science.

"We have a conviction that a boy should get his hands dirty on machinery. Many a scientifically-minded student has emerged from high school with his head crammed with the book facts of basic and applied science. He may be able to rattle off the names of the planets and the sequence of their orbits. But when he looks at the sky his expression is likely to be one of educated ignorance. He may have a smattering of astronomical knowledge, but, if so, it's usually on a par with that of the man who ducks into a planetarium for 10 minutes to get out of a rainstorm. He is totally unaware that a knowledge of astronomy can provide more enjoyment in later life than almost any other science, and that no hobbyist is more enthusiastic about his avocation or follows it with more avidity than the amateur astronomer.

"Let me admit that the curriculum of many schools is already crowded and that the addition of another course might prove to be the last straw. But what keeps most educators from embarking on a thoroughgoing program in astronomy is their budgets. Yet it can be shown that astronomy, or any other science for that matter, does not have to be either a time-consuming course or an item of heavy expense.

"The Millbrook astronomy program started in 1946 when, with the sympathetic help of a teacher, a group of boys built a telescope. It was a tubeless wooden affair, but it set a whole program in motion. Of course it was soon followed by a more elaborate instrument—no amateur is ever satisfied with his first telescope. Although this second telescope was a good one, it was far from expensive to build. It was constructed from such items as an old lawn-mower sharpener, which provided gears for the slow motion, a junked force pump, various pipe fittings and the top of a fire extinguisher. It is still being used.

"Up to this time the work in the subject had been on a hobby basis, but the School soon recognized its value and not only provided working space for an optical shop in the basement of one of the dormitories but also allocated working time by incorporating the project into the community service program. This meant that the boys could have the equivalent of four school periods a week to use as they wished. Their first act was to convert their working space into a laboratory for grinding mirrors and lenses. Soon there were many boys working on their own telescopes. More important, they were asking for instruction in astronomy and voluntarily giving up free time to learn more about it. The whole program up to this time—it had now been going for two years—had cost less than $60, which covered the two



The Millbrook Observatory (upper left), *its telescope* (lower right) *and earlier efforts*

telescopes. There were more than 20 boys taking part in it.

"The more they learned, the more they wanted to learn. Like most amateur astronomers, they wanted bigger and better instruments to work with. The outcome was a demand for a 'big' telescope. The School provided the money for a 12½-inch glass disk, and the boys set to work converting it to an astronomical mirror. By the fall of 1948 they had completed the mirror and mounted it in an oak tube supported by a wooden yoke framework for an equatorial mounting. This arrangement was neither beautiful nor easy to operate, but there was nothing wrong with the optical system and for five years it provided instruction and fed the enthusiasm of many boys. Again, the only expense involved was for the mirror blank, war surplus eyepieces and finder, and the wood for the mounting. If the thing had been made of gold it would have been worth it for the stimulus it provided. One outcome was a request for a course in celestial navigation, which was provided on a hobby basis by the School; another was membership in the American Association of Variable Star Observers; still another was the beginnings of a Schmidt telescope, a project which has resulted in a nearly completed primary spherical mirror 14 inches in diameter. The most impressive outcome was the carry-over into other fields. One boy gained an insight into the principles of optics which, in the light of his subsequent career, must be characterized as profound; another studied material far beyond the scope of ordinary secondary-school chemistry because he had become fascinated with the subject through his efforts to silver a mirror. All of the boys learned a great deal about precision measurements and how to handle tools and equipment.

"The 12½-inch telescope had one serious drawback: its size. Winters in New York State are not conducive to outdoor work at night, and the telescope was so big it could not be enclosed in anything smaller than a gymnasium. Since it was in an exposed location, little observational work could be done during the cold months, which was a source of unhappiness to the group. They insisted on undertaking work which extended through the year and had meaning and continuity. They wanted, for example, to set up a variable-star observing program and see whether they could interest professional astronomers in their results; to conduct a program of sunspot observations and make an effort to correlate sunspot activity with radio propagation; to experiment with celestial photography; to observe and measure the height of the aurora. In short, they weren't content to have built a telescope, which is too often the sole end of the amateur, they wanted to *use* it for something. But it seemed important to use it under circumstances which were at least reasonably comfortable. They decided to take their problem to the headmaster. Since a project like this was right in line with the community service program, they obtained his enthusiastic help and support and came away from the meeting resolved to build an observatory.

"The old telescope already had an excellent optical system which could be transplanted to their new enterprise. Consequently their chief need was the building itself and an adequate mounting. This was a real problem and required money. Careful planning was necessary, and so, in their mechanical drawing classes, they laid out plans and made estimates, and came up with the answer as to how much money they needed. Their next step was to make up a brochure outlining what they had done to date (complete with photographs) and what they hoped to do, and to distribute copies to everyone they thought might possibly help. The response from interested parents and friends was immediate and generous, and in an incredibly short time they had raised over $1,000. By Christmas of 1952 they were ready to start. All this was done by six boys: Michael Trimpi, John Stearns, Paul Ratner, Jack McLaughlin, Wendell Wickersham and Sumner Webber. They were the nucleus of a much larger group that did the subsequent work, and before the project was finished almost every boy in the School had a hand in the proceeding somewhere. During the remainder of the winter the boys concentrated on making wooden patterns for the aluminum castings in the mounting, fabricating the sheet steel base, setting up the gear system and finally assembling the whole structure. In this work they had a windfall. A local manufacturer, Gordon Anderson, became interested in their project and turned over the facilities of his machine shop to them, along with generous portions of his own time and energy. With his help they finished the mounting by spring. Then, hardly pausing for breath, they turned to the observatory itself.

"Nine weeks later they stepped back and looked at what they had accomplished. The completed structure was 17½ feet in diameter, built of waterproofed cinder block and surmounted by a dome which had started life as a silo top. The dome revolved on a track set on top of the cinder block and had a four-foot slit giving access to the heavens by means of a novel and original arrangement of casement shutters. Inside, the floor was built up 2½ feet over an eight-inch concrete slab, and set in the center of the slab was a massive pier which supported the telescope mounting. The latter was a far cry from the cumbersome wooden mounting the boys had wrestled with earlier. Made of steel and aluminum, it featured an open tube constructed of tubing threaded through cast aluminum rings. It had slow motion devices, slip-ring, setting circles, and needed only a motor to be complete. The astronomy committee was pretty well satisfied with what it had accomplished when they went home for the summer.

"After the boys returned in the fall they occupied themselves with odds and ends—clean-up work and laying out a program from which they could get the most use of their equipment. This was perhaps the most interesting phase of the whole project, because to the boys the construction of the observatory represented the beginning, not the end."

When we examined the structure it was clear that it was indeed a worthy beginning. The observatory met professional standards in every respect. The astronomy committee was on hand to show off its new plant, and three members—Alan Hubbard, Julian Strauss and Michael Madden—demonstrated the operation of the dome and the instrument, although, unfortunately, a heavy overcast prevented observation. Other members of the committee reviewed the current program with us and explained the significance of the data sheets and the photographic negatives made during the previous night. As the boys discussed their work it soon became plain why they had not been content merely to build a telescope. In the group discussion idea seemed to beget idea. It was easy to understand why the lone amateur often makes a telescope but does not use it. Without the challenges that arise from group discussion it is easy to overlook the thrills to be found at the eyepiece.

The members of the committee explained that they worked in two- and three-man teams. The teams are assigned as required to carry out a sequential program ranging from lunar and planetary observation through double stars, clusters and nebulae to the long established meteor and auroral work. In addition, the boys open the observatory to the student body twice each week.

The committee is now investigating the possibility of developing a program that would result in contributions of interest to astronomy itself. Plans are being laid for projects involving variable stars, sunspots, celestial transits, occultations, eclipses and celestial photography. Participation in the activity is open to anyone willing to acquire a knowledge of the constellations and other preliminary information essential to observation.

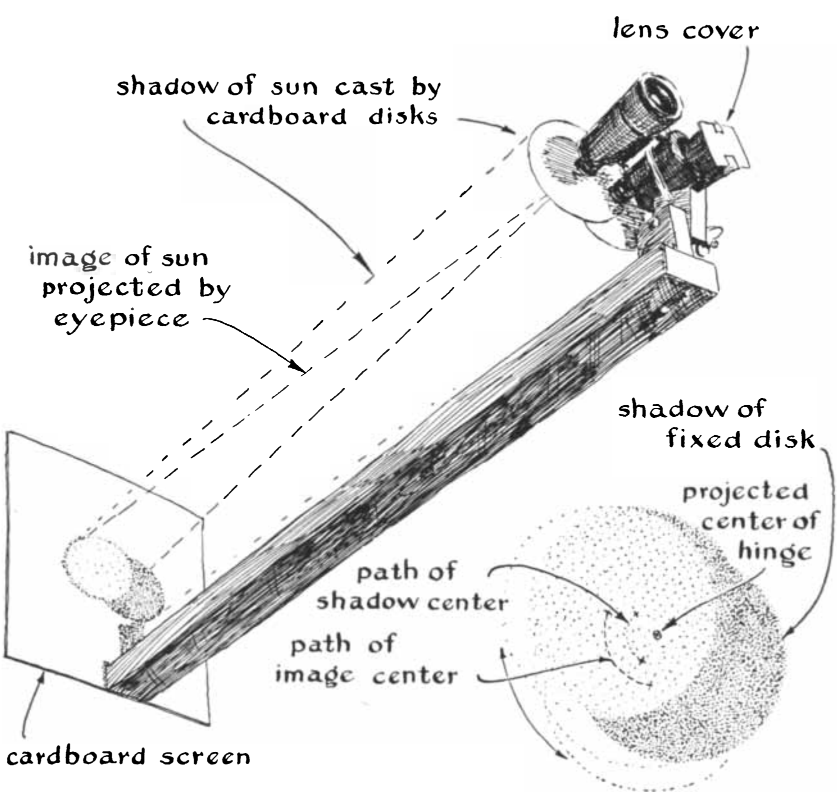
"In the course of developing the current program the boys considered many projects," writes Howard, "but recognizing both their own limitations and those of their equipment they wisely decided to stick to those phases of astronomy in which they were most likely to be successful.

"The astronomy program has now been in effect for eight years. During that time over 100 boys have taken part in it. The total cost, including money the boys have raised themselves, has been less than $1,600. It is true that the boys have spent considerable time on this project, but most of it has been their own. Actual class time has been the equivalent of four 35-minute periods a week.

"Here, then, is a way to introduce instrumental astronomy to a school curriculum. It is not presented as a universal solution to the problem, but simply as one means of attacking it. Its chief merits are that it is an inexpensive approach and that the program grows naturally because student interest is self-generating."

A binocular is two parallel telescopes permitting the simultaneous use of both eyes. Exhaustive experiments by the National Research Council have shown this arrangement results in a 4.5 per cent improvement over a single telescope in the performance of visual tasks. For this small advantage the user pays not only for the second telescope but also for the mechanism that must keep the telescopes parallel within only two or three minutes of arc. If eyestrain is to be avoided, this alignment must hold for all openings of the central hinge. It is not always realized how difficult this apparently simple mechanical problem is. The mechanism often loses its precision, and it is the mechanism, rather than the optics, which is the source of much of the difficulty with a binocular.

G. Dallas Hanna of the California Academy of Sciences, a paleontologist-zoologist whose hobby is the fine mechanisms of scientific instruments and who in wartime headed a group of 50 men and women who completely overhauled 6,000 U. S. Navy binoculars, says that not all professional binocular repairmen do a complete job of adjustment. Some slight it by adjusting, or collimating, for only a single opening of the hinge. Moreover, says Hanna, "not even the manufacturers consistently take the trouble to put their binoculars in perfect collimation. If I had a dollar for every 'new' pair I have had to collimate, I could retire. We must remember that we are dealing with movements of mechanical and optical parts measurable by thousandths of an inch, and such displacements produce unfortunate results when magnified by the optical levers involved. The binoculars are not built—perhaps could not be built—for the rough treatment they receive from many users. It is impossible to keep the telescopes parallel. It is the general belief of shop repairmen that if the designers of binoculars would tear down a few of their instruments after they have been out in service they might alter greatly the details of their construction. Nevertheless people like the instruments with all



A simple apparatus for testing the alignment of binoculars their faults and there are millions of them in use. Because many of these faults are practically unavoidable, it can be said that a good binocular has not been made, and it is doubtful whether one ever will be." Hanna gives as his personal preference for escaping all the faults an instrument that is not a binocular at all. It is a monocular; specifically half of a 6×30 binocular.

In his chapter on the overhaul and adjustment of binoculars in *Amateur Telescope Making: Book Three*, Hanna provides for three levels of dealing with binoculars. The first is six quick, simple tests for evaluating a binocular in a store prior to purchase. The second goes to the other extreme: the construction of a binocular-collimating instrument by which a binocular may be adjusted so precisely that, as he says, it "may be used continuously for hours without the slightest strain, and the observer soon forgets that he is looking through an optical instrument at all." Though it is almost impossible to attain the highest degree of precision without a collimator of this quality, few will care to make one for a single job of collimating, so Hanna describes a third procedure that will give a passable result without it. To these approaches Felix A. Luck added in this department for October, 1951, a method for making and using a collimator that could be built mainly of wood in a few hours and which would give a reasonably close approximation using the sun. Vern E. Hamilton of Inglewood, Calif., now contributes another method which uses the sun and a homemade apparatus that can be built in less than an hour. Hanna says it should result in better adjustment than some of the binocular repair shops turn out. Hamilton writes:

"Here is a method requiring no precision equipment and by its very nature giving collimation at all interocular settings, not at one average setting alone. I believe it could be called a 'primitive' method since nothing need be square and no measurements are made, the disks being drawn with a primitive instrument, the compass.

"At right angles to one end of a two-by-four about eight feet long, fasten a white cardboard focusing screen about two feet square. At the other end fasten an adjustable mount for the binocular so that it will be approximately in line with the center of the focusing screen. This mount should be designed so that half of the binocular may be clamped securely while the other half is being swept through the interocular adjustment.

"Focus the eyepieces for distance and

place the binocular in the mount. Point the whole arrangement toward the sun, so that two enlarged images of the sun fall on the focusing screen. Cut from cardboard two separate disks about two inches larger in diameter than these solar images. When arranged in the manner about to be described the disks will cast a shadow with a fuzzy edge, or penumbra, and an area of total shadow, or umbra, which will be slightly larger than the solar images. In the center of the disks cut a hole just the right diameter to slip snugly over the binocular eyepiece. Cut a rough quadrant out of each disk so that it will clear the other eyepiece, and press the disks onto the eyepieces.

"When the arrangement is again pointed at the sun, the disks will cast a shadow large enough to hide completely the shadow of the binocular itself. Cover the right objective, clamp the right side of the binocular firmly, and put the left side at one extreme of the interocular setting. Adjust the mount by moving the entire binocular so that the solar image on the focusing screen is centered on the left disk shadow.

"Now, while sweeping the left side of the binocular through the entire interocular adjustment to the other extreme, note any shifting of the solar image in relation to the disk shadow. If the solar image remains centered with the disk shadow, the left optical axis is parallel (collimated) with the interocular adjustment axis. If, on the other hand, there is a relative movement between the solar image and disk shadow, rotate the mount (moving the entire binocular) by cut-and-try until a position is found where the solar image and disk shadow will remain fixed in relation to each other (but not centered) while being swept back and forth through the interocular adjustment. When this condition is obtained, adjust the optics of the telescope so as to bring the solar image on center with the disk shadow. If all has gone well, the solar image will now remain centered on the disk shadow while the left side is swept through the interocular adjustment. If not, repeat the entire sequence as a refining process with each side until the binocular is collimated. As a double check remove both objective covers and see whether both solar images can be centered on their corresponding disk shadows at each extreme of the interocular setting. If there is any accumulated error, repeat the steps with the individual telescopes until no error is detectable, or at least until no error is detectable at your own interocular setting. Thus, instead of disregarding the interocular adjustment axis, it is used as the common reference line for collimating the two binocular telescopes.

"This method is based upon the fact that in a properly collimated binocular any two corresponding pencils of light from the eyepiece are parallel to each other, and the central pair must be parallel to the interocular adjustment axis if the telescopes are to be parallel to each other at all interocular settings. The parallel rays of the sun are used to construct base lines and project the exit pencils simultaneously. The sun, eyepiece disks and disk shadows form the base lines, and the solar images represent the exit pupils. When the binocular is oriented in space so that the solar images can be made to remain fixed (but not necessarily centered) in relation to the disk shadows while being swept through the interocular adjustment, then the adjustment axis is parallel to the base lines. After this condition is obtained, the optics are adjusted to bring the solar images on center with the disk shadows. The solar images (representing the exit pencils) will now satisfy the full requirement for collimation by remaining centered as well as fixed in relation to the disk shadows (base lines) while being swept through all interocular settings.

"If it is desired to collimate the binocular for one interocular setting, the method reduces to an extremely simple one. The only requirements are the cardboard masks for the eyepieces and a focusing screen propped up on the ground approximately at right angles to the rays of the sun. The binocular is set at the desired interocular setting and pointed at the sun so that one of the solar images is centered on its disk shadow. The optics of the other telescope are then adjusted to bring its solar image on center with its disk shadow, and the binocular is collimated for a single setting. Of course, if one does not wish to tackle the job of collimation, the foregoing simplified method may be used to check quickly the collimation of a doubtful binocular without any disassembly whatever.

"The amount of error may be estimated by aligning one solar image with the corresponding disk shadow and estimating the displacement of the other solar image and disk shadow. This displacement, divided by the distance from the binocular to the focusing screen, is the tangent of the apparent error angle. The apparent error angle divided by the power is the actual error angle.

"The formulas in Donald H. Jacobs' *Fundamentals of Optical Engineering* give a tolerance for non-parallelism in 7× binoculars of only 3.75 minutes of arc for convergence and 1.3 minutes for divergence horizontally and/or vertically. On a focusing screen eight feet away 1.3 minutes of arc amounts to one fifth of an inch off-center permissible between solar image and disk shadow. This amount can be detected by the method, and it is best not to leave any detectable vertical or horizontal divergence in the binocular at all. As indicated, some convergence can be left, provided that it does not turn into divergence as the binocular is swept through the interocular adjustment."

Practical objections have been raised to the adverse effects caused by the earth's rotation when using the sun with this method. Hamilton says: "This gives some trouble, but the error need not be left in, since the rigorous check is made by setting the binocular at one extreme interocular setting with the telescopes uncovered. The solar images are set to 'lead' the shadows and the solar images are watched until the earth's rotation brings them onto the shadows, when they are compared for on-center. This is repeated at the opposite extreme interocular setting. Any small error which may have accumulated from the previous steps can thus be detected and the steps repeated with the individual telescopes to bring the error within the acceptable limits.

"The fuzzy shadow of the cardboard disk is a very real problem, and its only solution lies in the fact that checking with the solar image utilizes the 'sense of symmetry' enhanced by the apparent doubling of the eccentricity. I usually work inside the fuzzy penumbra by making the solar image a little smaller even than the umbra, and if the image is off center, say one fifth of an inch, the dark ring around the outside of the solar image will be two fifths of an inch narrower on one side than the other.

"Another small source of trouble is that the solar image is not quite sharp either. Of course the eyepiece could be focused so that the solar image would be sharp, but the eyepiece would not then be in the position of average use, and since the method is sensitive enough to pick up eccentricity in the eyepiece lenses and threads, a faulty collimation would result. Incidentally, a good test when buying a binocular is to step outside in the sun, rest the binocular on a firm support and turn the eyepiece while watching the solar image on the ground. Of course the image will come in and out of focus, but any eccentricity will be readily apparent."

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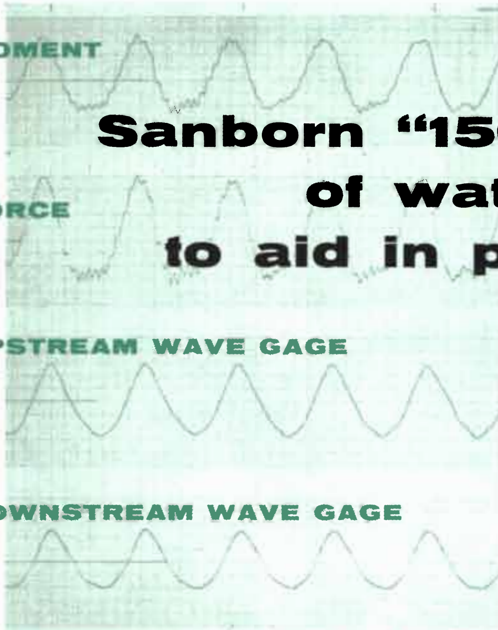

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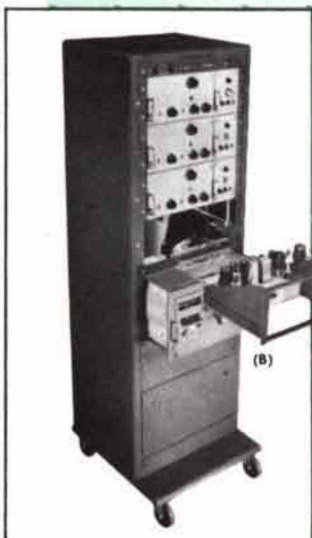

Preamplifier (A) in position to plug into a driver amplifier with frame, combined with power supply and control panel (B) which is normally already in place in the basic cabinet assembly.

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