SCIENTIFIC AMERICAN

WEATHER BALLOON

FIFTY CENTS

June 1954

Beauty bath for metals

Two important elements of a nickel plating process are the canvas-bagged anodes and plating solution above. A third is Amberlite® ion exchange resins.

Rinse water from a single plating plant may total 200,000 gallons daily. Amberlite resins permit recovery of metals and water from rinse solutions. Costs are cut because valuable metals are salvaged and the water made suitable for reuse—even as boiler feed. Stream pollution is virtually eliminated. Metals recovered include nickel, copper, chromium, gold, and silver.

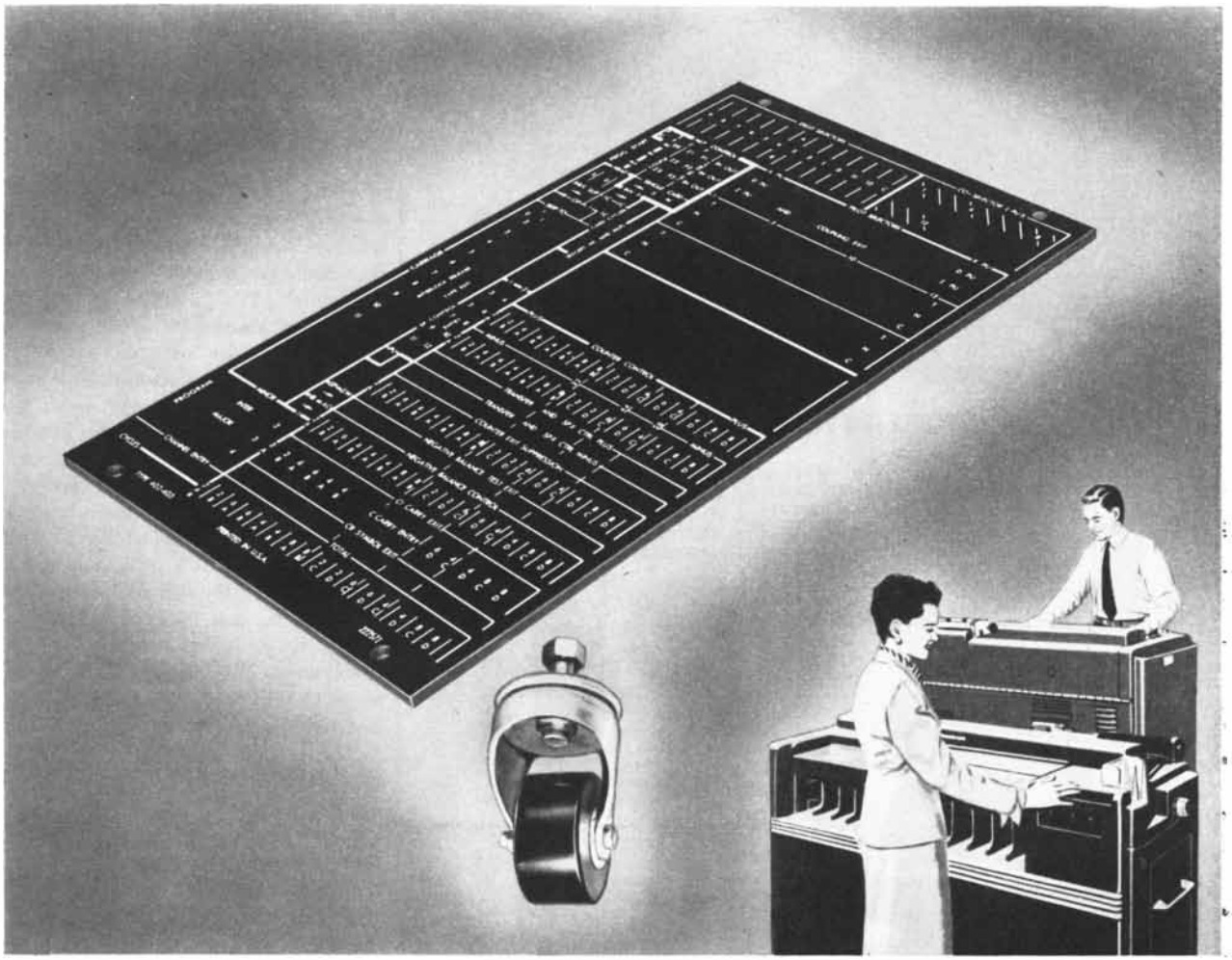
Other metal-treating industries benefit from ion exchange, too. Amberlite ion exchange resins, for example, remove metallic contaminants from alodizing, anodizing, and chromic acid stripping baths. Because the baths can be used again and again, savings are large.

Why not write us about your problem? Find out why ion exchange is the right way to metal recovery, why the resin that's *right* is *Amberlite*.

Ask for this complete review of ion exchange in the metals treating industry.

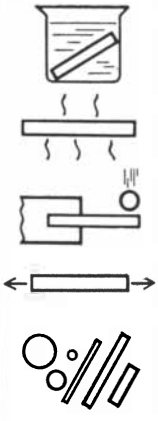
ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION, PHILADELPHIA 5, PENNSYLVANIA



Head and feet for an office worker who neither errs nor tires

Properties of Synthane



In addition to those mentioned in the text, Synthane has the following important properties:

Chemical resistance. Synthane resists most acids and alkalis in moderate solutions, and corrosive atmospheres.

Temperature resistance. Synthane is thermosetting, will not flow under elevated temperatures. Grades resisting up to 400° F are available.

High impact strength. Synthane stands up well in applications where it is subject to vibration, pounding and shock loads.

Mechanical strength. Synthane exhibits excellent strength under tension, compression, and other loads. It will not delaminate.

Availability. Synthane issupplied in more than 33 grades of sheets, also in rods, tubes and molded-laminated or molded-macerated parts. A complete fabricating service is available.

• The uncanny ability of tabulating machines to do complicated jobs quickly and accurately is famous. One of the materials which helps to make this possible is *Synthane*—a laminated plastic.

Synthane serves as the base for the brains of the machines—the plug boards upon which the control circuits are set up. *Synthane* is excellent for the purpose because of its combination of high dielectric strength, resistance to moisture, dimensional stability and ease of machining. *Synthane* is printable, too—circuit designations are readily printed on its surface.

On tabulating machines, casters that are friendly to office-type flooring are needed. Casters of molded-macerated *Synthane* fill the bill. *Synthane* caster wheels are strong, do not flatten by constant pressure, and do not mar office floors.

Should you require a versatile material—one with many properties in combination—*Synthane* may be your answer. Our catalog tells the full story. To receive yours, drop us a note on your letter-head. Synthane Corporation, 2 River Road, Oaks, Pa.

Our 25th Year

SYNTHANE CORPORATION, OAKS, PA.

SYNTHANE

LAMINATED S PLASTIC

LETTERS

Sirs:

All who are seriously interested in the sound development of scientific research will welcome the illuminating article on the National Science Foundation by Lawrence P. Lessing [SCIENTIFIC AMERICAN, March] and will applaud his vigorous plea for increased interest in and support for basic scientific investigation. Mr. Lessing, however, made one comment about the Rockefeller Foundation which might lead to misunderstanding and which I would like to clarify.

Mr. Lessing speaks generously of the contribution of the Rockefeller Foundation to basic research in the past, but he also states that the Foundation has now "diverted most of its curtailed funds to emergency measures to raise agricultural and living standards abroad." In several respects this latter statement does not accurately reflect the facts.

The funds of the Foundation, viewed in relation to vastly increased needs, and compared to the larger amounts available from government, corporate and other sources, may appear "curtailed." In absolute terms, however, the Foundation's income, and appropriations from income in 1952 and 1953 were the highest of our 40-year experience.

It is also incorrect to say that the Foundation has used "most" of its funds for the purposes mentioned. Appropria-

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RCA announces revolutionary NEW Electron Microscopes

Now—from RCA, pioneer and world leader in electronic research, come two great new electron microscopes. The EMU-3A with both 50,000 and 100,000 volt accelerating potential is destined to be recognized as *perfection in electron microscopy* —the ideal tool for advanced research requiring highest resolution, maximum magnification and critical control. The EML-1A, a 50,000 volt instrument, has every important feature needed for peak performance in a wide range of research and control functions.

Here are some of the key engineering advances and improvements that make these precision instruments invaluable:

- High resolving power—20 and 30 Angstrom Units
- Consistently higher magnifications—useful to over 200,000 diameters.
- Choice of 50,000 volt and 100,000 volt accelerating potential
- Vertical column construction for stability and accessibility
- Single set of pole pieces for all magnifications
- Insensitive to vibration and magnetic fields
- Roll film and plate cameras—choice of four different picture sizes
- External control of objective aperture
- Binocular Viewer
- Large 5″ x 5″ direct view, high brightness screen
- Push Button Controls—Unusual ease of operation
- Selected Area and Reflection Diffraction

What can these important new instruments do for you?

Factual information on the features, construction and operation of the revolutionary new RCA Electron Microscopes is yours for the asking. WRITE: Radio Corporation of America, Dept. F-111, Building 15-1, Camden, N. J.

RADIO CORPORATION of AMERICA

tions for the support of the agricultural sciences were approximately 5 per cent of the total in 1950 and 1951, and 8 and 9 per cent, respectively, in 1952 and 1953.

Furthermore, we do not consider our support of agriculture in the category of "emergency measures." In the projects operated by our own staff, and in those supported by grants, our interest is consistently directed toward work at the basic scientific level. Our cooperative program with the Ministry of Agriculture of Mexico began 11 years ago and that in Colombia is four years old. Both of these operating programs are devoted primarily to research in genetics, pathology, soils and related fields fundamental to the long-range problem of increase of production.

In addition to aiding these operating programs in agriculture, the Foundation is making appropriations for research in agriculture; a necessary condition for this support is that the research project be fundamental and long-range in nature. Certain activities under current study might not exert any influence on the world's food supply for 10, 25 or even 50 years.

WILLIAM C. COBB

Office of Publications
The Rockefeller Foundation
New York, N. Y.

Sirs:

Reading the published portion of Hans Hahn's Vienna Circle lecture [SCIENTIFIC AMERICAN, April] unaccountably left me in a lyrical frame of mind. This produced the commentary which follows:

A line boasting thickness is
suddenly bred,
Fathered by logic and thick
pencil lead.
Bend it at random and lay it on
thick
To generate squares or even a
brick.

Curves without tangents are
possible, too,
For example take wave curves, as
some people do,
And ignore continuity,
progression and such.
(Use a thick pencil again in the
clutch.)

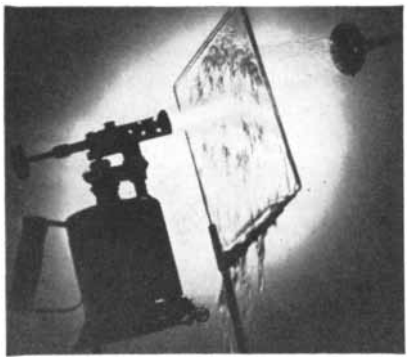
Fracture straight lines until
they are points

CORNING GLASS BULLETIN

FOR PEOPLE WHO MAKE THINGS

Tricky welding problem solved. Sometimes you back into a problem. For instance, heat generated by welding instrument panels into place was raising havoc in a plant where they assemble flying machines.

Glass windows used in the panels had to be mounted *before* the welding trick, but invariably they broke under the high temperatures the welding generated. Racking his brains for a solution to this vexing problem, someone thought of trying one of the VYCOR brand glasses. It worked. Now welders weld away to their heart's content without thought of setbacks from breaking glass.



A piece of VYCOR brand glass takes the heat from a blowtorch on one side and a cold water spray on the other without cracking or melting.

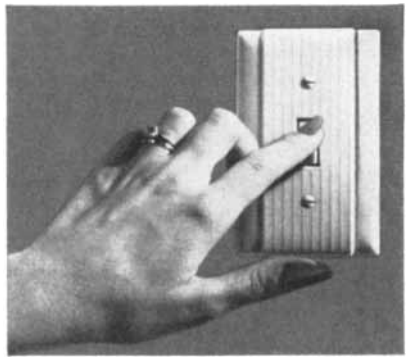
The ability of VYCOR brand 96% silica glass to stand up under remarkably wide variations in temperature—from below freezing to 1800° F.—makes it an exceptionally useful material. Our technical men attribute this ability to what they call "special thermal properties." We think you'll get some idea of just how much of this "thermal" stuff it's got from the picture above.

▶ An interesting piece entitled, "*Glass that laughs at heat*" tells a lot more about this fascinating material. We will be glad to send you a copy.

Glass that clicks because it doesn't. Elusive mercury (the only metal that flows at room temperature) helps take the click out of some electric wall switches.

But, it's a PYREX bulb no bigger than an unshelled peanut that keeps the mercury in line. Result—silent light from switches that don't click when you flick.

In all honesty we must admit we don't make this ingenious little bulb. What we *do* supply is the PYREX tubing to make the bulb that makes the silent switch.



How come *glass* for this tough but delicate service? Well, first of all, mercury being corrosive (as well as elusive) unites with most materials —but *not* with nonporous glass. Then, there's the little matter of insulation, not to be overlooked when directing traffic through electrical circuits. And, to frost the cake, glass (as you've probably found out) is often made so you can see through it. See-through-ability in this case makes inspection of the finished product quick and sure. And finally, glass can be joined to metal.

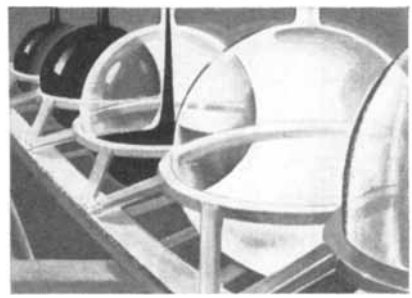
The glass used in the silent mercury switch is made from one of the more than 50,000 glass formulas on tap at Corning. Each formula has been developed in the search for just the right balance of mechanical, chemical, thermal, and/or electrical properties to satisfy some specific design or use problem. Maybe one of them can serve you.

▶ Any time you'd like to get a little deeper into the myriad uses to which product designers and engineers are putting glass, we'd be glad to aid your cause. The profusely illustrated booklet, "*GLASS and You*" gives a comprehensive picture of glass at work and play. Drop us a line and we'll whisk your copy on its way.

How to obsolete an elephant. When billiard balls aren't made of elephant ivory, chances are they're made of plastic.

After searching for a better molding material, a couple of billiard ball makers are now using glass with quite some success. Taking their cue from these game firms, others have also found glass molds useful in making plastic products with a minimum of fuss—precision items such as insulators for the radio and TV industry, and catheters to aid the cause of medicine are examples.

What's really important isn't so much what's being made in glass molds, as what has been proved about them. For one thing, because glass is nonadhesive, the plastic material doesn't stick to the mold—nor the mold to the plastic material. And when they're made in large enough quantities, glass molds are inexpensive enough to be expendable—just crack 'em off and throw 'em away when the plastic is set.



Sketch showing how billiard balls are molded in glass. When the plastic is set and cured, glass mold is simply cracked off and ball is ready to finish.

Glass molds can cut processing cost, too. Since products come out so smooth, they require less finishing. You can even hasten curing time by using dielectric heat.

▶ If plastic molding is on your mind, maybe you'll want to learn more about putting glass to work. Why not tell us what you have to mold and see if we can supply the answer.

If the items discussed here seem unrelated to your problem, we still may have what you need at our fingertips. We'd count it a pleasure to hear from you.

Corning means research in Glass

CORNING GLASS WORKS 30-6 Crystal St., Corning, N.Y.

And string them together without
any joints.
A curve? Bless my soul, you're
naive. Don't you know
That the points are still lines
without tangents that show!

Three countries expand. 'Tis a
wonder to see
How quickly they annex all
territory.
They meet without touching all
over the place,
For the land gobbled up does not
occupy space.

Poor wave curve, it lacks
"connectivity of the small"—
No short-cut from one end to the
other at all.
But circles run rampant,
connected throughout—
Diametrical short-cuts are in
logical doubt.

So abolish intuitive concepts by
Kant.
Now worship logic and take up
the chant.
Too many succeeded to ken what
we mean.
New jargon is needed to put up
a screen.

But let us consider what Hahn
might have said,
If Kant based his claims on pure
logic instead.
Would Hahn nonetheless have
remained a logician?
Or would he have urged us to use
intuition?

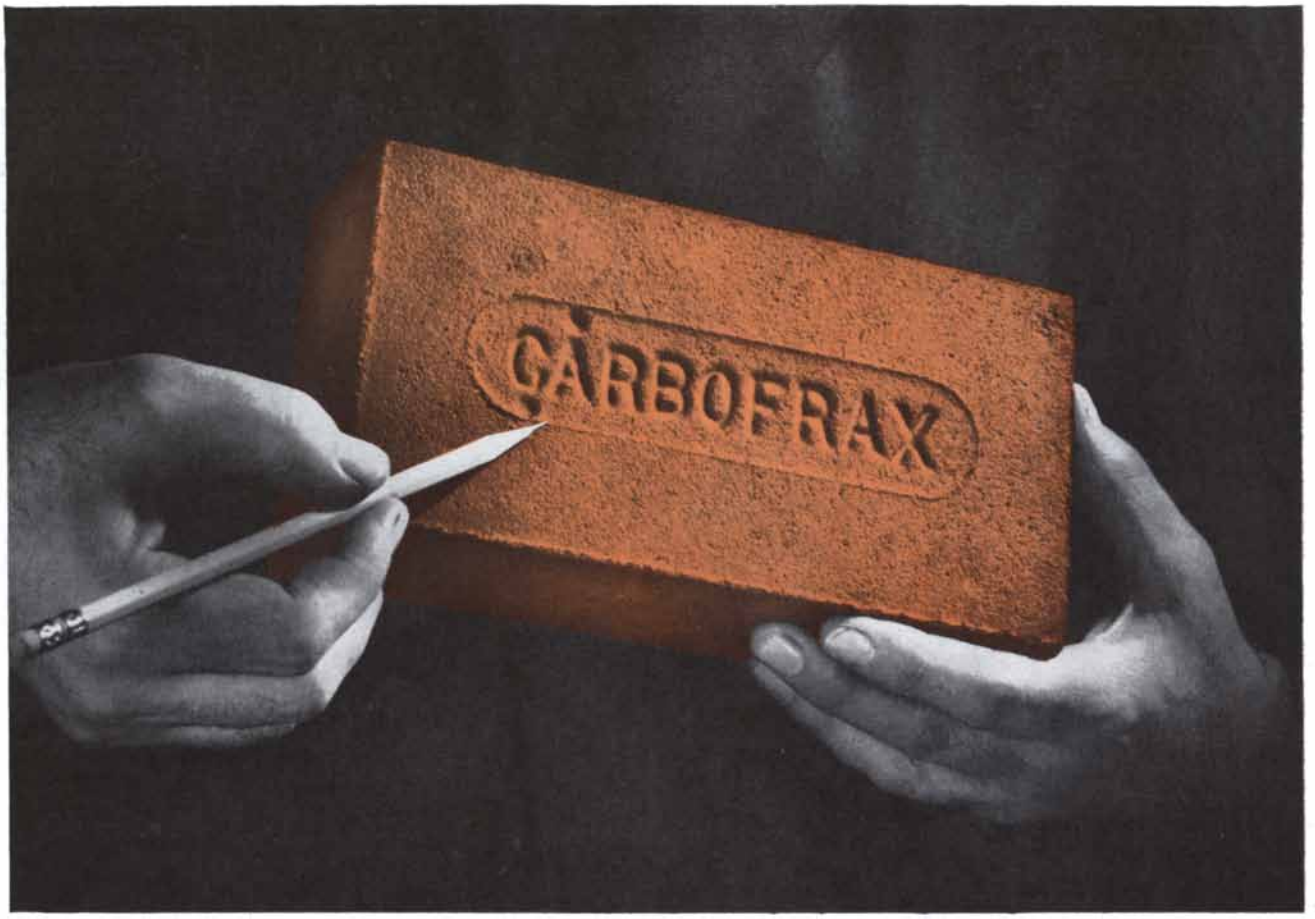
WALTER R. PAVELCHEK

Engineering School
Tufts College
Medford, Mass.

Errata

The photograph at the left on page 57 of the article "The Shape of Cities" [Scientific American, April] is incorrectly identified as showing Greensboro, N. C. The city shown is Portland, Me.

The illustration on page 72 of the article "Muscle as a Machine" [Scientific American, March] should be credited to Professor W. Kuhn and Dr. B. Hargitay.



When some brick sell for as little as 10¢ each . . .

Why is this brick worth $1.70?

Suppose you put a muffle arch of these $1.70 brick in a furnace and — as a direct result — *doubled productive capacity*. Suppose you put them in the floor of another and it *lasted 50 times longer*. Suppose you put them in the hearth of a third and *eliminated 30 days downtime* in one year. Then at $1.70 apiece these brick would be a terrific buy. And are. Because these figures come from real, live companies! Companies that replaced ordinary refractories with CARBORUNDUM's super refractories!

Granted, you can't always get such spectacular results. But you usually get a combination of benefits. For example, by lasting longer, CARBORUNDUM's refractories automatically cut costly downtime losses . . . and maintenance expense . . . and labor. And by using heat more efficiently, you not only increase production . . . but cut fuel costs . . . and cut rejects. In short, their value is more — much more — than just to resist heat.

So if you could use a material that is far harder than metals . . . or one that conducts heat nearly as rapidly as chrome-nickel steel . . . or another that insulates well at temperatures above 3000 F — we have them. These "man-made minerals" range from a ceramic fiber (looks like cotton), to a superdense refractory that's cast, like a metal. And our engineers can show you how to combine these materials to exploit their complete range of properties.

WHY NOT CHECK UP? It's smart to at least know what super refractories *can do*. This coupon is your private introduction.

CARBORUNDUM
Registered Trade Mark

Dept. Y-64, Refractories Division
The Carborundum Co., Perth Amboy, N. J.

☐ Please send complimentary descriptive booklet.
☐ I'd like to talk with one of your engineers.

Name _____ **Position** _____

Company _____

Address _____

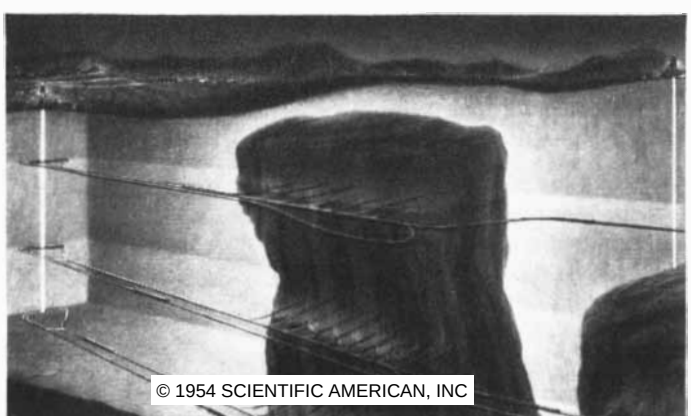
_____

Look what's happening in metals

They Turned

HOW BRIGHT A LIGHT? On summer nights the N. Y. Giants play ball at the Polo Grounds. Cool? Comfortable? You bet. Fans pack the park. Anyone can find time to go. Eight banks of 120 lights, each 1500 watts, turn night into day. Each bank takes miles of *copper* wiring.

75th BIRTHDAY FOR BUTTE, MONTANA. Incorporated in 1879, Butte has seen generations of men mine its ore—first for gold, then silver, then copper. Now, in Butte's Diamond Jubilee, new, more efficient methods are used to mine the hill for copper, zinc, lead and manganese. Here—in cross section—is Anaconda's Greater Butte Project, started in 1952. The Kelley Shaft is shown at the far left.



HOW COPPER SERVES THE ELECTRICAL INDUSTRY. There's more to electricity than wires and cables. Generators, turbines, switchgear and transformers are needed—all with many copper and copper alloy parts. For these The American Brass Company, an Anaconda subsidiary, has for 75 years turned Butte's copper into the many shapes, sizes and alloys used by the electrical industry.

Night Into Day

This is Light's Diamond Jubilee. Read how an incandescent lamp and a Montana copper mine, both 75 years old, help make life brighter, better.

Back in 1879 the National League was just a pup, racing around Abner Doubleday's diamond.

Tom Edison was working nights . . . *by gaslight.*

Finally, on October 21, the Wizard of Menlo Park coaxed a slim filament to glow for 40 hours. In a crude glass bulb the incandescent lamp was born.

In that same year, at Butte, Montana, brawny miners were sinking a new mine shaft, christened "The Anaconda." With sledge and dynamite they worked closer to a fabulous vein of copper ore—the first of the large discoveries that earned Butte the title of "the richest hill on earth."

It takes plenty of copper

The world rubbed Edison's wonderful lamp. Its miracle of light has glowed brighter every year. In homes. In factories. On gay Broadway. On the farms. All over the globe.

But not without help from *copper.*

Edison needed only ten feet of copper wire in 1879. Today *half* of all the copper produced becomes wire.

Where does it come from?

To help supply this copper, mining companies over the years have explored and developed many new ore deposits. And they have successfully sought new ways to mine and process lower-grade ores economically.

For instance, the rugged prospectors of old Butte would blink in amazement to see the new Kelley Shaft opened in Butte in 1952. It is now 2200 feet deep. Up that shaft Anaconda is hustling 12,000 tons of ore per day.

Blazing a trail of light

Because Tom Edison tinkered . . .

Because Butte miners—and others elsewhere—dug deeper and farther...

Because America's light and power companies now produce over 400 billion kilowatt-hours of energy a year...

Light's Diamond Jubilee is the brightest ever!

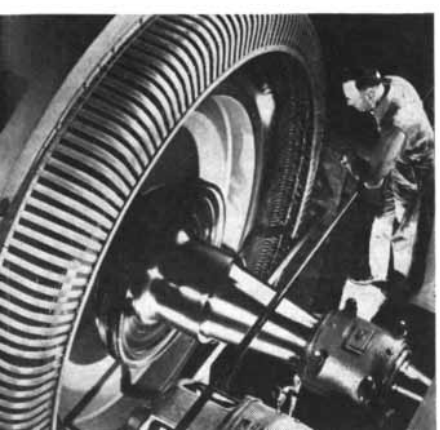
54275

ANACONDA

"ANACONDA" IS A REGISTERED TRADEMARK

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.



WHY DO POWER CABLES LAST LONGER TODAY? Under their lead sheaths, most big electrical cables beneath the street are insulated with paper, impregnated with oil. As years go by, this oil tends to break down. To extend—often double—the life of the insulation, Anaconda Wire & Cable Company makes a special power cable (Type CB®) with built-in colloidal-carbon-black tapes. These tapes "sponge up" impurities and keep the oil "young."

50 AND 100 YEARS AGO

SCIENTIFIC AMERICAN

JUNE, 1904: "The flying machine invented by Orville and Wilbur Wright, which made a successful flight at Kitty Hawk, N. C., last December, had another trial near Dayton, O., on May 26, which the brothers say was successful. Great secrecy was maintained about the test, and but few witnessed it. The machine, after being propelled along a track for the distance of a hundred feet, rose in the air and flew a short distance, when it dropped. This was due, the inventors say, to a derangement of the gasoline engine that furnishes the power. In the fall the propellers were broken, and the test could not be repeated."

"Frederick Soddy has performed an experiment from which he concludes that radium is not the product of the disintegration of uranium. Writing in *Nature*, he says, 'Twelve months ago I purified a kilogramme of uranium nitrate until the quantity of radium present was less than 10^{-13} gramme. This was the limit of detection by means of the electroscope employed, using the maximum or equilibrium amount of accumulated radium emanation as the test for the presence of radium. It was arrived at by direct comparisons with the examination from a standard milligramme of radium bromide, by subdivision until its presence could no longer be detected. Unfortunately, owing to the large amount of radium in the laboratory, subsequently introduced for the purpose of the helium research, the electroscopes have been affected, and it is not possible at the present time to be sure of such minute effects as originally. But it may be stated that less than 10^{-11} gramme of radium has accumulated in the kilogramme of uranium during the past twelve months. This practically settles the question so far as the production of radium *from uranium* is concerned. The result, of course, may be explained by assuming the existence of intermediate forms between uranium and radium. But from a general consideration of the whole question from the point of view of the disintegration theory, several such

SPLITTING HAIRS

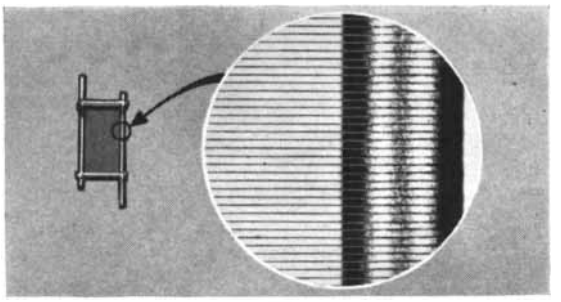
TO SPEED CALLS

This coaxial system electron tube amplifies more voices at the same time because of wider frequency band—made possible by bringing grid and cathode closer together.

To triple the voice-carrying capacity of coaxial cable, Bell Laboratories engineers had to create new amplifying tubes with the grid placed only two-thirds of a hair's breadth from the cathode. Furthermore, the grid wires had to be held rigidly in position; one-quarter of a hair's shifting would cut amplification in half.

Working with their Bell System manufacturing partners at Western Electric, the engineers developed precise optical means for measuring critical spacing insulators. On a rigid molybdenum grid frame they wound tungsten wire three ten-thousandths of an inch thick. To prevent the slightest movement they stretched the wire under more tension for its size than suspension bridge cables, then bonded it to the frame by a new process.

The resulting tube increases coaxial's capacity from 600 to 1800 simultaneous voices—another example of how Bell Telephone Laboratories research helps keep your telephone system growing at the lowest possible cost.



Grid is shown above left, actual size. Picture at right, enlarged 15 times, shows how wires are anchored by glass bond. They will not sag despite nearness of red-hot cathode.

BELL TELEPHONE LABORATORIES

IMPROVING TELEPHONE SERVICE FOR AMERICA PROVIDES CAREERS
FOR CREATIVE MEN IN SCIENTIFIC AND TECHNICAL FIELDS

hypothetical forms, each with an extended life, must be assumed. So that unless modifications are made in the theory, which at present are not justifiable, the evidence may be taken as indicating that uranium is not the parent element of radium. The experiments will be continued from year to year with the kilogramme of uranium nitrate.' "

"For the purpose of insuring pure food for the people of this country Secretary Wilson has established a microscopic laboratory in connection with the chemical division of the Department of Agriculture. Already it has been demonstrated that unscrupulous dealers are palming off artificial coffee and other impure food on the public."

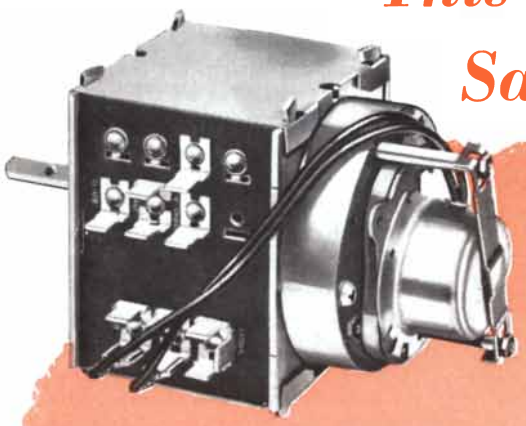
"Dr. Jules Rehns of Paris has been carrying out several experiments to ascertain the precise effects of radium burning upon the skin. If the rays of one sixteen-hundredth part of an ounce of radium bromide are applied, no pain is experienced, nor is there any mark left at the time of application, but twenty-four hours later a red mark appears, remains for a fortnight, fades and leaves behind a scar similar to that of a burn. If the application be continued for ten minutes instead of five, the mark becomes visible in eighteen hours. Ulceration does not occur unless the radium has been applied for at least an hour."

SCIENTIFIC AMERICAN

MAY, 1854: "Leverrier has recently read an interesting paper before the French Academy upon the asteroid planets, their eccentric orbits and irregularities. All of their orbits are especially characterized by eccentricities, and by considerable inclinations. It therefore follows that the hypothesis stated by Dr. Olbers—that the asteroids (some of which he discovered) were derived from the wreck of a larger planet that had exploded—is incompatible with the real truth, inasmuch as the forces necessary to launch the fragments of a given body in such different routes would be of such improbable intensity as to render it mathematically absurd."

"Geoffroy Saint-Hilaire and other eminent naturalists in France are beginning to turn their serious attention to the acclimatization or domestication of animals which have hitherto been totally un-

This Mallory Timer Switch Saves Work for Millions...



How Many More Will It Serve?

First choice of home appliance manufacturers, the Mallory Interval Timer Switch masterminds the varied operations of automatic washing machines, clothes dryers and dishwashers . . . thus eases tiresome chores for millions of housewives.

Now this precision-built Mallory switch is going to work outside the kitchen and laundry.

In one instance it continues to serve the housewife as it controls the newest of beauty shop hair dryers . . . a versatile device that drys, cools and sterilizes air . . . puts a better-than-ever finish to that morale-boosting hair-do. In another case, the Mallory timer switch acts as a watchman on an improved sterilizer for doctors' and dentists' instruments.

As a consumer, there's no sure way to tell where you'll find the unique Mallory switch next working for you . . . perhaps as a more flexible and effective control in a home air conditioner.

If you, as a manufacturer, have a product that requires automatic time control of an operating cycle, contact Mallory to learn how our experience in switch development and production can work to improve performance and increase sales appeal for your product.

Manufacturers who do business with us expect such results from Mallory products and processes in electronics, electrochemistry and specialized metallurgy.

P.R. MALLORY & CO. INC.

MALLORY

SERVING INDUSTRY WITH THESE PRODUCTS:

Electromechanical • *Resistors, Switches, Television Tuners, Vibrators*
Electrochemical • *Capacitors, Rectifiers, Mercury Batteries*
Metallurgical • *Contacts, Special Metals and Ceramics, Welding Materials*

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

known to Europe, or known only as objects of scientific curiosity. Within the last month they have received for the Jardin des Plantes a number of Yaks from China—an animal which Buffon says 'is more precious than all the gold of the New World.' In Thibet and China this animal serves as a horse, an ass, a cow, and a sheep; he bears heavy burdens, draws large loads, supplies milk, has flesh which is excellent, and hair which can be wrought into warm clothes. To naturalize him, therefore, in Europe would be an immense service to mankind, and as he bears cold bravely the French naturalists have every hope that they will be able to do so—though, by the way, the late Lord Derby made the attempt and failed."

"The Swiss journals give the following details relative to the discoveries recently made in consequence of the extraordinary fall in the water in the Lake of Zurich. About one hundred feet from the right bank of the Lake, opposite the village of Mellen, there have been found several rows of piles formed of trunks of trees. The piles are about a foot apart, with an interval of sixteen feet between the rows. These piles support enormous beams, which form a very large area. Between the piles there have been found the skeletons of animals which are no longer to be seen in Switzerland, but no trace of any domestic animals. These remains, which are considered to have belonged to the ancient Celts, are under examination by a commission of antiquarians."

"Since the fall of the Wheeling Suspension Bridge, articles have appeared in a number of our daily papers condemnatory of iron as a material for such structures. There can be no doubt, in our opinion, but the breaking down of so many iron bridges in our country can be traced to the bad quality of iron used in their construction—it did not possess sufficient elasticity. All iron is iron, just as all wood is timber; but there are just as many varieties of the former as of the latter. Yet how small is the amount of knowledge possessed by the most experienced engineers of the different kinds of iron in comparison with our knowledge of wood. Let civil and mechanical engineers look more to the quality of the iron which they use for various purposes, and the community will not be so often inflicted with painful accidents on sea and land—from the bursting of boilers, the fracturing of the shafts and beams of engines, and the breaking down of iron bridges."

Your business is in the Age of Electronics

Electronic test instruments used daily at Friden include Hewlett-Packard oscillators, voltmeters, power supplies, electronic tachometers and the new, amazingly versatile -*hp*- electronic counters.

Electronic test instruments save engineering time, cut manufacturing costs at Friden

Like manufacturers in many fields, Friden Calculating Machine Co., Inc., finds electronic test instruments save hours of engineering time and cut production costs. Friden engineers use these new measuring tools of industry to evaluate circuits, determine electrical requirements, check stability, match relay closing times and study performance of pilot models. Friden production workers use similar instruments in rigid quality control inspections.

Hewlett-Packard is a pioneer and world leader in electronic test instruments—the basic measuring tools used today throughout manufacturing and process industries, in scientific research, communications and military installations. Correct application of such equipment is of the first importance; Hewlett-Packard field engineers can tell quickly whether any of over 200 different -*hp*- instruments are applicable to your needs. A letter stating your requirements will receive prompt attention; investigate today! Write Dept. S.

Railways are increasingly large users of electronic equipment—for signaling, safety and communications. -*hp*- instruments help keep railway electronic devices functioning correctly, dependably.

Textile experts now measure wool's strength, hand and durability by electronics; improve wool products with information instruments like -*hp*- harmonic wave analyzers, amplifiers and voltmeters provide.

Throughout science and industry, electronic test instruments make routine measurements faster, more accurately; increase knowledge by making other kinds of measurements once not possible. Electronic test instruments work by measuring or comparing electrical impulses from natural or man-made sources.

ELECTRONIC MEASURING INSTRUMENTS

HEWLETT-PACKARD COMPANY

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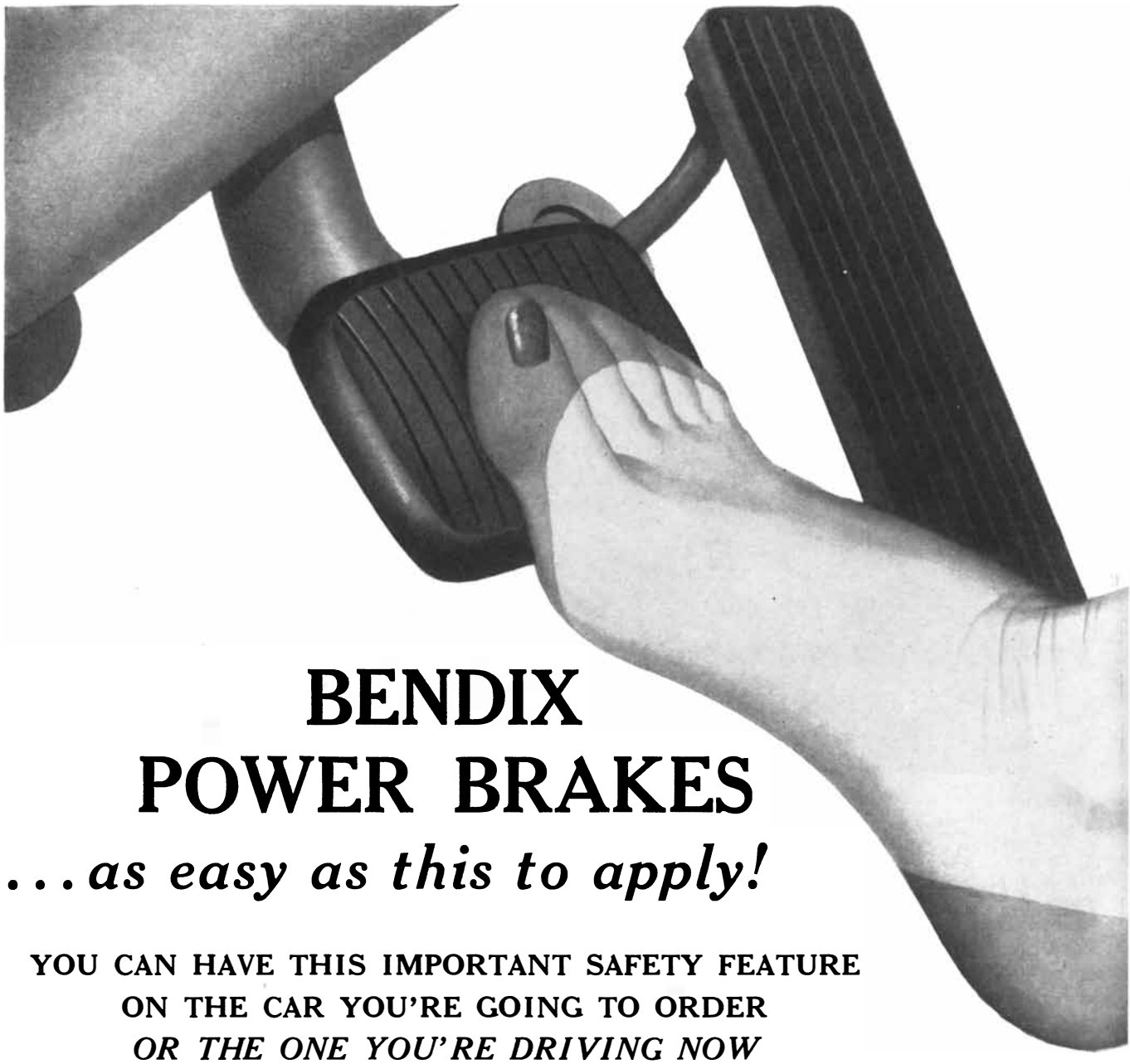
2930

FIELD ENGINEERS IN ALL PRINCIPAL AREAS



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...as easy as this to apply!

YOU CAN HAVE THIS IMPORTANT SAFETY FEATURE ON THE CAR YOU'RE GOING TO ORDER *OR THE ONE YOU'RE DRIVING NOW*

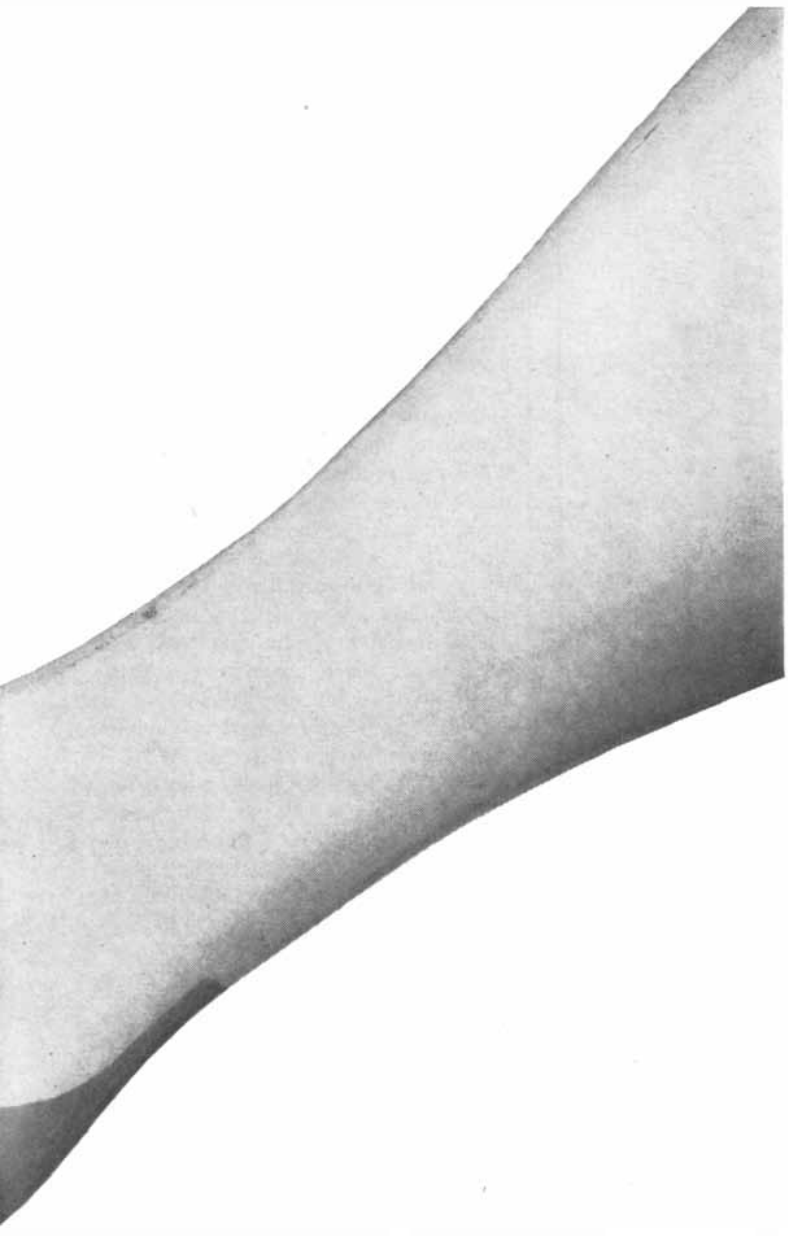
WHEN you buy your next new car, here is something you certainly should order with it—Bendix* Power Brakes—the safest, easiest, most proved power brake in the world.

Just as Bendix* Power Steering makes parking and turning so much easier, our power braking gives you quicker, surer, easier stops. Bendix is the pioneer and leader in power braking for cars and trucks, producing over 4 million units since 1939. That's why most car manufacturers offering power brakes selected Bendix for their 1954 models.

And now, even though you are not planning on a new car, you can get Bendix Power Brakes. Car dealers and garages from coast to coast are now stocked with models specifically engineered for your present car. It's about a two-hour installation.

How Far Does Bendix Stretch?

Bendix touches just about every basic industry with one or more of our thousand products. Heaviest in automotive and aviation components, Bendix contributes to scores of other industries as well. Our fine weather instruments are used by bureaus all over the world; railroads use Bendix communications radio for greater efficiency; your boy probably has one of our good coaster brakes on his bike; maybe you or your neighbors enjoy the dependability of Bendix* Television. Our scientists have worked from the beginning in the fields of nuclear physics and guided missiles and we have just introduced Ultra Viscoson—a new and better method of measuring, recording and controlling viscosity of hundreds of different fluid materials in any stage of processing.



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aviation instruments and components; foundry.

ECLIPSE MACHINE, ELMIRA, N. Y.
Stromberg carburetors, electric fuel pumps, starter drives, coaster brakes.*

SCINTILLA, SIDNEY, N. Y.
aviation ignition systems; industrial engine magnetos; diesel fuel injection.

BENDIX RADIO, TOWSON, MD.
radar; auto, railroad, mobile and aviation radio; television.

MARSHALL-ECLIPSE, TROY, N. Y.
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meteorological instruments; precision instruments and recorders.

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electronic tubes; dynamotors, inverters.

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automotive, marine and small engine carburetors.

BENDIX-SKINNER, DETROIT, MICH.
micronic filters.

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telemetering equipment; hydraulic and electric actuators; depth recorders; boat steerers.

CINCINNATI, CINCINNATI, OHIO
automatic viscosity regulators, nuclear products.

BENDIX COMPUTER, LOS ANGELES, CALIF.
digital computers.

HAMILTON, HAMILTON, OHIO
jet engine controls and aircraft pumps.

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power steering and automotive devices.

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aviation components.

MONTROSE, SOUTH MONTROSE, PA.
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THE AUTHORS

JOHN B. PHELPS and ERNEST C. POLLARD ("Fort Monmouth") are the secretary and chairman, respectively, of the Scientists' Committee on Loyalty and Security, a group sponsored by the Federation of American Scientists. Their Committee has just completed an investigation and a report on the large series of security suspensions in the Army Signal Corps Engineering Laboratory at Fort Monmouth, N. J. Both men are at Yale University, Phelps as a graduate student, Pollard as professor of physics. Phelps was born 24 years ago in a small Iowa town, educated at Morningside College, Sioux City, and Colorado College. At Yale, working toward his Ph.D., he is a research assistant specializing in experimental nuclear physics. Pollard was peculiarly fitted to evaluate the Monmouth situation, for, after a distinguished decade in nuclear physics, he put in four war years as staff member at M.I.T.'s Radiation Laboratory working on radar. Born in Yünnan, China, in 1906, he received his Ph.D. from Cambridge University in 1932. Since the war he has set out to make a new career for himself in biophysics.

R. H. SIMPSON ("Hurricanes") was pitched into meteorology as a small boy in Corpus Christi, Texas, during the great hurricane of 1919. Winds lashed the coast and piled water 14 to 15 feet high in the streets. "Our family," he writes, "managed to swim to higher ground and the safety of the Court House several blocks from our home while many others failed to make it." Since then he has had an intense interest in tropical cyclones, often going out of his way to get close to the vicious "eye" of a hurricane to study it. After courses at Southwestern University and Emory University, he joined the U. S. Weather Bureau in 1940 as a meteorologist. In 1945 he also became a technical adviser to the Air Force. He has organized a number of research flights into hurricanes from Panama, Bermuda and Guam over the last eight years. He is now Aviation Weather Specialist in Washington. In his spare time he is developing a radio-beacon balloon which when dropped in the eye of a hurricane will provide continuous radio bearings on the storm center.

RAY F. SMITH and WILLIAM W. ALLEN ("Insect Control and the Bal-

World's largest high-alloy weld is 67 square inches...
IT'S BEING DONE AT CLEVELAND PNEUMATIC

In a blinding shower of sparks two solid steel railroad car axles can be welded into one length in only 108 seconds . . . or . . .

Two heavy-wall alloy steel tubes 20″ in diameter, 1″ wall, can be joined with a weld that is actually as strong as the tube walls.

In the Cleveland Pneumatic plant, the world's largest and most powerful general-purpose flash-butt electric-resistance welding machine is now at work joining aircraft components. This machine can butt weld high-alloy steel pieces having a total cross-sectional area of as much as 67 square inches. With low-carbon material, this area can be as large as 100 square inches.

A limited amount of this machine's extra time is available now on a contract basis. It can be useful to manufacturers who have the problem of getting highest-quality large-area welds on high-alloy steels at low unit cost.

Write for Booklet D-64, which describes this machine and its capacities, and also tells you how our Contract Welding Department can work for you.

Cleveland Pneumatic
Tool Company CLEVELAND 5, OHIO
Department D-64

BALL-SCREW MECHANISMS • AIR-OIL IMPACT ABSORBERS • *World's Largest Manufacturer of Aircraft Landing Gears*

ance of Nature") are on the faculty of the University of California. Both are Californians by birth and both specialize in the economic aspects of insects and insect control, the former with relation to agricultural problems, the latter with regard to the dynamics of insect populations. Smith, an assistant professor of entomology, took his Ph.D. at the University in 1946. At the California Agricultural Experiment Station he has developed insect-control programs for alfalfa and cotton. His main extracurricular interest is a species of Mexican beetle—an interest which has carried him on several field trips to that country. In 1950 he and his wife and three children went on an eight-month camping and collecting tour through Mexico. Allen, who is 32 and a junior assistant entomologist at the university, received his doctorate in 1952. He served a four-year hitch on destroyer duty as a lieutenant in the Navy.

W. GREY WALTER ("The Electrical Activity of the Brain") is a pioneer in the use of electroencephalography for translating the minute electrical currents of the human brain into physical patterns which may be studied for the light they throw on brain processes. Walter, a physiologist, has pursued his studies for the past 15 years at the Burden Neurological Institute in Bristol, England. Now 43 years old, he was educated at Cambridge University, where he did graduate work in neurology, and went on to work in a London hospital in the years before the war. A prolific writer and lecturer on his subject, and a popular broadcaster on this and related topics for the BBC, he is the author of *The Living Brain*.

J. W. WESTWATER ("The Boiling of Liquids") became interested in boiling phenomena 12 years ago at the University of Delaware while doing graduate research on condensing vapors. The boiler apparatus used to supply the vapors happened to be made of glass, making visible the curious actions going on. He went to work in earnest on the problem in 1950, shortly after joining the chemical engineering staff of the University of Illinois, where he teaches heat transfer and other courses. Born in Danville, Ill., in 1919, Westwater took a B.S. in chemical engineering from the University of Illinois in 1941, then switched to the University of Delaware, where he received the first Ph.D. granted by that institution in 1948. He expects to be studying boiling for an indefinite number of years. His hobby is photography,

SANTOCEL...

Can this remarkable silica aerogel improve YOUR processing or products?

What is Santocel?

Santocel is a finely divided, free-flowing silica aerogel. So fine, in fact, that one pound has a *surface area of over 17 acres.*

What are the outstanding properties of Santocel?

1. Santocel has a large, relatively inactive surface area.
2. Santocel is insoluble in organic solvents.
3. Santocel has a remarkably high oil adsorption value, making it an outstanding thickening agent, particularly for nonpolar organic materials such as styrene monomer, petroleum oils, etc.
4. Santocel has essentially the same refractive index as the common vehicular solids of surface coatings and plastics. You can incorporate it or disperse it in clear film-forming liquids without causing haze, or use it with colored pigments without changing the color or decreasing brightness.
5. Santocel gives remarkable thermal insulation since it contains 94% "dead air." The pore space in the Santocel structure is so small that heat energy is transferred through it very slowly.
6. Santocel imparts thixotropic properties to organic-based colloidal systems and solutions.
7. Santocel is not abrasive, because its ultimate particle size is extremely fine.

A Few of Santocel's Many Applications: To thicken polyester or epoxy resins • As a reinforcing filler for silicone rubber • To control viscosity in making printing inks • To thicken hydrocarbons to make greases.

Santocel: Reg. U. S. Pat. Off.

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MONSANTO CHEMICAL COMPANY, Dept. S-1
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Inorganic Chemicals Division
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Gentlemen:
Please send booklet, "Industrial Applications for SANTOCEL"

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CHEMICALS – PLASTICS

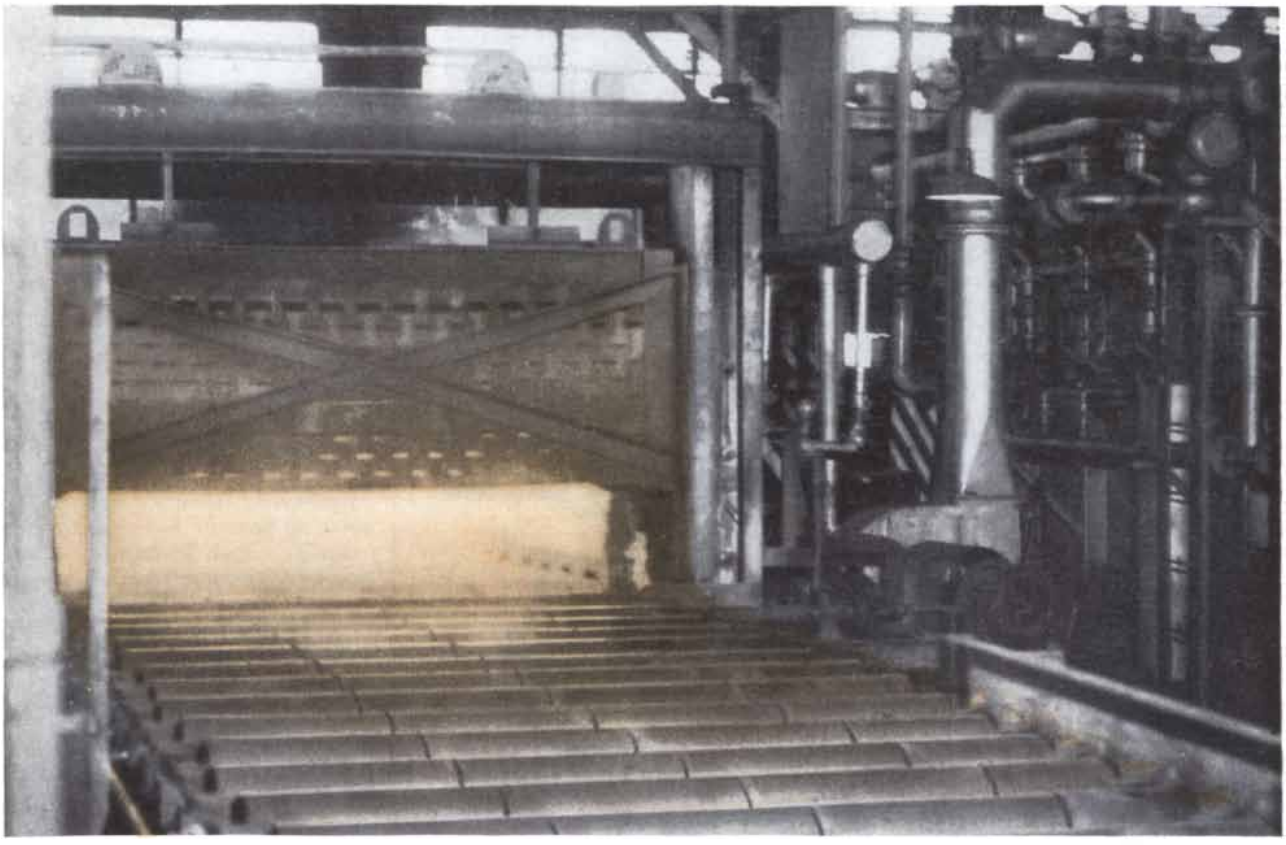
SERVING INDUSTRY...
WHICH SERVES MANKIND

and he put it to use to illustrate his article.

ALBERT TYLER ("Fertilization and Antibodies") has long been a member of the Biology Division of the California Institute of Technology, specializing in embryology, fertilization and immunology. As a student of chemistry at Columbia University in the late 1920s, he became interested in the work of the late great geneticist Thomas Hunt Morgan. He persuaded Morgan to take him on as a graduate student, and in 1928 he transferred with Morgan to Caltech. Tyler completed his graduate work there and has remained ever since. In those years Morgan had largely given up his famous work on fruit flies and heredity, feeling that it was in other good hands, and had shifted to a subject in which he was no less talented—experimental embryology. Tyler's bent was in that field. One of the problems was to find out why the sperm of a common hermaphroditic sea squirt was incapable of fertilizing its own eggs while fertilizing those of almost any other individual. Tyler was led by that problem to his present work on fertilization and development.

JAMES R. NEWMAN ("Laplace") is a member of the Board of Editors of this magazine.

J. L. GIDDINGS, JR. ("Early Man in the Arctic") is a Texan whose early interest in wild life and migratory birds evoked an urge to travel. During a two-year mountain climbing trip in Colorado he decided to go north and enroll in the Alaska Agricultural College and School of Mines at Fairbanks (later the University of Alaska). He completed his college course there in 1932 and stayed on. Summers he worked as explorer for a mining company, and on his own discovered a method for cross-dating ancient spruce and tamarack remains buried in the frozen silt. This brought him to the attention of A. E. Douglass of the University of Arizona, the noted student of tree rings. Giddings obtained a degree from Arizona in 1941, spent three years in the Navy and finally got his Ph.D. in 1951 from the University of Pennsylvania, where he now teaches. Most summers since 1939 he has spent on field trips to the Arctic. Two of his three children were born in Fairbanks. He and his wife, who also is an anthropologist, are currently trying to adjust to an old stone farmhouse at Valley Forge, Pa. As archaeologists, they are reluctant to offend so ancient a structure with electricity or other modern conveniences.



3800 hours at 2150 deg. F.

The HASTELLOY alloy X rollers in this gas-fired heating furnace have been in use for 3800 hours. They operate in a neutral atmosphere at 2150 deg. F. They are also subjected to mechanical and thermal shock as they come in contact with the cold sheet metal being heated. A recent inspection showed that the HASTELLOY alloy X parts are still in excellent operating condition.

The rollers were fabricated from HASTELLOY alloy X sheet, 3/16 in. thick. The sheets were formed into shells 7½ in. in diameter and six feet long. The shells were then slipped over 2-in. water-cooled pipe, and refractory material was packed into the space between the shells and shafts. Spiders on the shafts were used to keep the shells concentric.

HASTELLOY alloy X has excellent forming characteristics, and good creep and stress-rupture properties. At 1200 deg. F. this nickel-base alloy has an ultimate strength of 82,000 lb. per sq. in., and even at 1500 deg. F. the ultimate tensile strength is 48,000 lb. per sq. inch. Its outstanding resistance to oxidizing, reducing, or neutral atmospheres makes it especially useful in furnace applications.

For information on prices, sizes, and properties of HASTELLOY alloy X write to any of the district sales offices listed below.

"Hastelloy" and "Haynes" are registered trade-marks of Union Carbide and Carbon Corporation.

HAYNES TRADE-MARK ALLOYS

HAYNES STELLITE COMPANY

A Division of Union Carbide and Carbon Corporation

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THE COVER

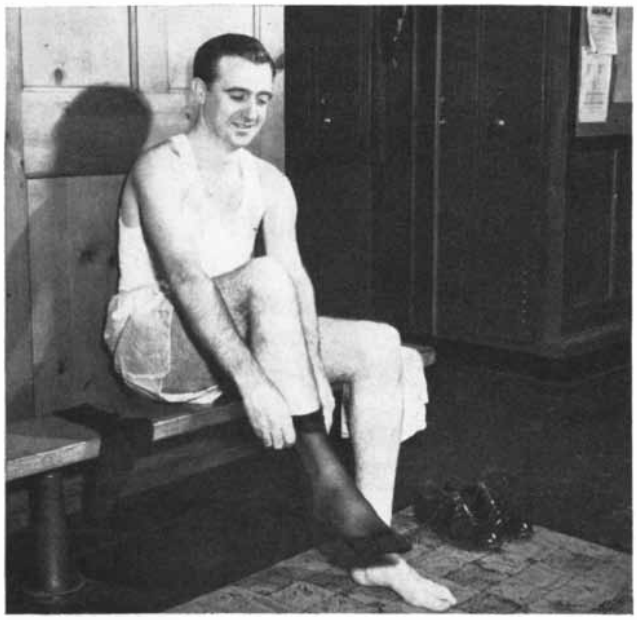
The photograph on the cover shows a U. S. Weather Bureau balloon a few seconds after its release. Trailing behind the balloon are a red parachute and a radiosonde which continuously transmits information about air pressure, temperature and humidity. Such balloons are released from certain Weather Bureau stations at internationally agreed times twice a day. They may also be launched into special meteorological situations such as the eye of a hurricane (*see page 32*). Two days before it is used, the balloon is preconditioned in a heated cabinet to insure against failure. Made of latex and filled with helium, the balloon has a diameter of seven feet when it is released. Its average ceiling height is from 60,000 to 75,000 feet. When the balloon bursts at its ceiling, the radiosonde drops back to earth, its fall broken by the parachute.

THE ILLUSTRATIONS

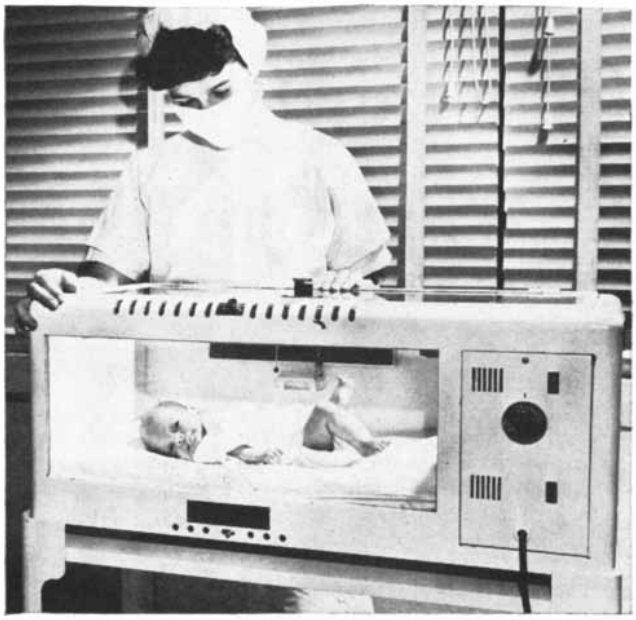
Cover photograph by Paul Weller

Page	Source
32	U. S. Weather Bureau
33	U. S. Navy
34-36	Irving Geis
37	U. S. Weather Bureau
38	Ray F. Smith and William W. Allen
39	Eric Mose
40-41	Eric Mose
42	Eric Mose
55	Hans Wild
56-60	Burden Neurological Institute
63	Hans Wild
65	J. W. Westwater
66	Sara Love
70-75	Albert Tyler
76	Burndy Library
77	Sara Love
81	New York Public Library
82-84	Bunji Tagawa
86-88	J. L. Giddings, Jr.
91	Black Star
99-104	Roger Hayward

How would YOU solve these two problems?

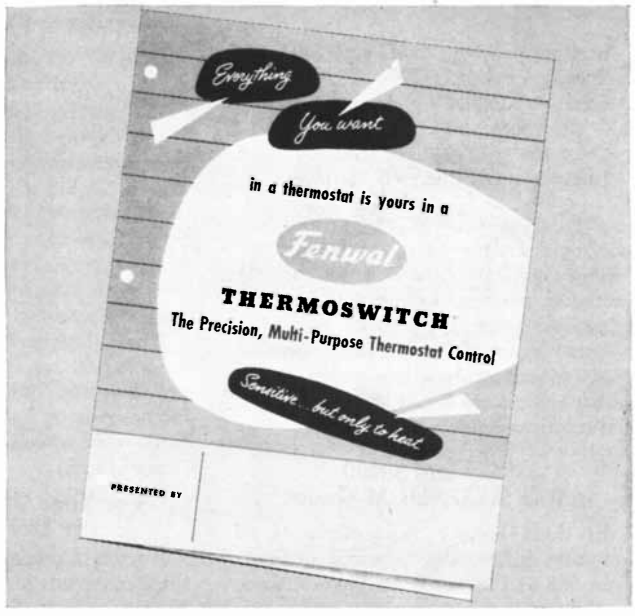


1. MEN AND WOMEN BOTH like nylon fabrics. Important key to producing successful nylon fabrics is the heat-setting process. Temperature-control must be accurate, and reliable yet readily adjustable. "National" Nylon Heat Setting Machines used by the leading textile mills employ THERMOSWITCH® units in the heated rollers . . . get highest efficiency . . . greatest safety . . . most economical fuel consumption.



2. BABY INCUBATOR MUST BE SAFE. Engineers who design Armstrong Baby Incubators say "Safety is a *must* where babies are concerned. That is why all our baby incubators are tested and approved by Underwriters Laboratories. That is why we use only Fenwal THERMOSWITCH units to control all-important temperature and humidity. Inspection reports on more than 22,000 THERMOSWITCH units show a remarkable picture of consistent reliability."

3. THIS IS IT — the Fenwal THERMOSWITCH control is simple — compact shell contracts or expands *instantly* with temperature changes, opening or closing electrical contacts. Adjustable and highly resistant to shock and vibration. Fenwal THERMOSWITCH units are solving temperature problems and helping to improve the final product throughout all industry.



4. SEND FOR THIS BROCHURE for complete explanation of the unique THERMOSWITCH unit. Also ask for more detailed, illustrated discussions of the problems above. Fenwal engineers will be glad to help you solve your temperature control problems involving heat, humidity, radiant heat, pressure and other variables. Write Fenwal Incorporated, 306 Pleasant St., Ashland, Massachusetts.

Fenwal

THERMOSWITCH®

Electric Temperature Control and Detection Devices

SENSITIVE . . . *but only to heat*

High-Purity Fused Alumina Grains... What Can They Do For You?

FUSED alumina, with its inherent properties of hardness, chemical stability and high density, is one of the most widely used electrochemically refined materials. It is produced in many forms. One of these, Norton 38 ALUNDUM* grain has proved successful for many applications demanding high purity. Electrically fused from Bayer-processed alumina, this white grain is shown by typical chemical analysis to be 99.49% pure Al_2O_3. It is insoluble in common solvents and extremely resistant to reduction. It is an amphoteric refractory and has high dielectric strength. Other characteristics include:

Melting point — about 3600°F.
Specific gravity — 3.94
Crystal structure — hexagonal system (rhombohedral division)
Hardness — 9.0 Mohs' scale
Index of refraction — 1.76 mean

Typical uses of 38 ALUNDUM grain are: pure oxides and sintered refractories, refractory cements, catalyst supports, heat exchange pebbles, wear-resistant parts, laboratory ware.

Other types of Norton fused alumina with unique combinations of properties which make them highly suitable for special requirements include:

38500 and 38900 AWIF ALUNDUM Grains

In these further refinements of 38 ALUNDUM grain, the terminal designations 500 and 900 indicate particle sizes. In the 38500 grain, average and maximum particle sizes are 19.5 microns and 50 microns, respectively; in the 38900 grain average and maximum particle sizes are 7.5 microns and 30 microns, respectively. Particle sizes are consistently very uniform. AWIF signifies "acid-washed and iron-free."

Although these grains have the same physical properties as 38 ALUNDUM grain, their special processing to remove objectionable elements results in unusually high purity. A typical chemical analysis reveals:

Al_2O_3 — 99.86% • Fe_2O_3 —.01 to .05%
SiO_2—.01 to .05% • Na_2O —.01 to .08%
C — <.01% • pH — >4.1

Very good electrical resistance, high heat conductivity and inertness are further advantages of 38500 and 38900 ALUNDUM grains for applications in both the electrical and chemical fields. In addition to their use in electronic tubes, as illustrated, other possible uses include the manufacture of ceramic pieces, particularly electronic components where the inherent qualities of this extremely pure grain are of great value.

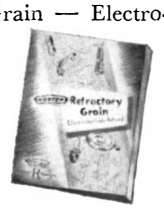
Other Norton Electrochemically Refined Materials

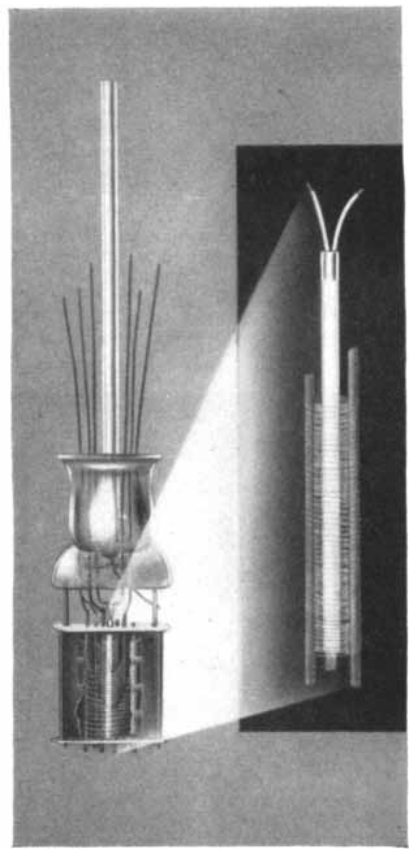
We made ALUNDUM grains the subject of this message. But we could just as well have chosen any of the long list of well known Norton electric furnace materials — CRYSTOLON* silicon carbide, MAGNORITE* magnesium oxide, NORBIDE* boron carbide, FUSED STABILIZED ZIRCONIA, and many others, including a number still undergoing research and development.

These high-melting materials which have varied applications in many fields, are also the basic ingredients of the famous Norton Refractory Rx's — refractories *engineered and prescribed* for the widest range of uses.

For Your Own Applications or Developments

Norton Company not only supplies these materials in their crude form, but has extensive facilities for processing and fabricating — and is ready to work with you in engineering materials to your particular requirements. A new booklet "Norton Refractory Grain — Electrochemically Refined" contains detailed information on these interesting materials. NORTON COMPANY, 545 New Bond Street, Worcester 6, Mass.





IN ELECTRONIC TUBES Norton 38500 or 38900 ALUNDUM fused alumina grain is used to coat heater filament tubes (shown enlarged). The grain is put in suspension and the filament is drag coated, spray coated or electrically deposited (cataphoresis).

NORTON
REFRACTORIES
Engineered... Rx... Prescribed
Making better products... to make other products better

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

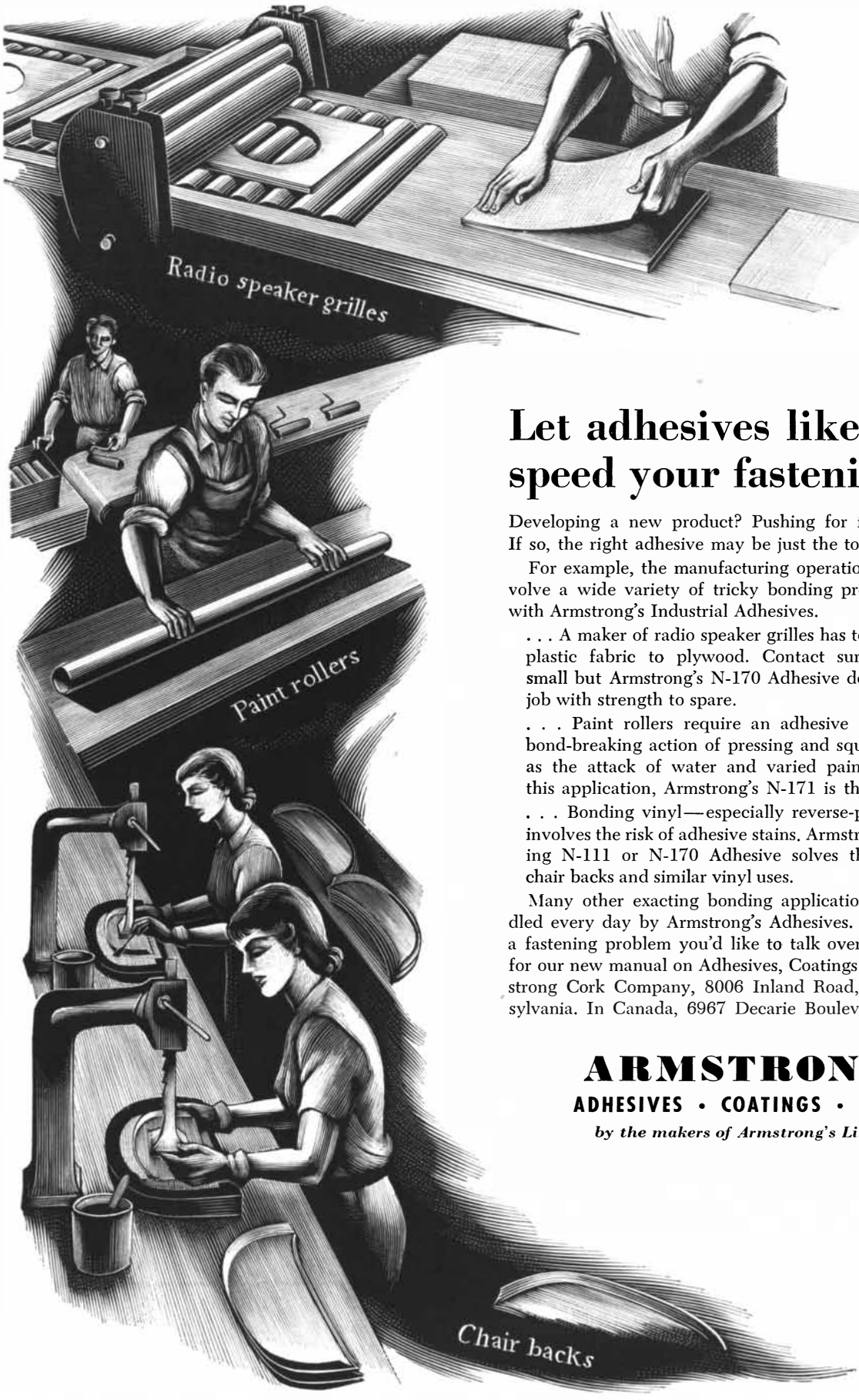
SCIENTIFIC AMERICAN

Established 1845

CONTENTS FOR JUNE, 1954 VOL. 190, NO. 6

ARTICLES

DEPARTMENTS



Let adhesives like these speed your fastening jobs

Developing a new product? Pushing for faster production? If so, the right adhesive may be just the tool you need.

For example, the manufacturing operations shown here involve a wide variety of tricky bonding problems, all solved with Armstrong's Industrial Adhesives.

. . . A maker of radio speaker grilles has to bond a woven plastic fabric to plywood. Contact surfaces are very small but Armstrong's N-170 Adhesive does this hairline job with strength to spare.

. . . Paint rollers require an adhesive that resists the bond-breaking action of pressing and squeezing, as well as the attack of water and varied paint solvents. For this application, Armstrong's N-171 is the answer.

. . . Bonding vinyl—especially reverse-printed types—involves the risk of adhesive stains. Armstrong's non-staining N-111 or N-170 Adhesive solves this problem on chair backs and similar vinyl uses.

Many other exacting bonding applications are being handled every day by Armstrong's Adhesives. Perhaps you have a fastening problem you'd like to talk over. Call us or write for our new manual on Adhesives, Coatings and Sealers. Armstrong Cork Company, 8006 Inland Road, Lancaster, Pennsylvania. In Canada, 6967 Decarie Boulevard, Montreal.

ARMSTRONG'S

ADHESIVES • COATINGS • SEALERS

by the makers of Armstrong's Linoleum

SCIENTIFIC AMERICAN

JUNE, 1954 VOL. 190, NO. 6

Fort Monmouth

A report of the Scientists' Committee on Loyalty and Security, which examined the results of the widely publicized security investigations at the Signal Corps Engineering Laboratories

by John B. Phelps and Ernest C. Pollard

Early last October the Army's Signal Corps Engineering Laboratories at Fort Monmouth, N. J., one of the most important military research centers in this country, suddenly became the subject of sensational and alarming newspaper headlines. Senator Joseph R. McCarthy, chairman of the Senate Permanent Subcommittee on Investigations, announced the discovery of a situation which had "all the earmarks of extremely dangerous espionage." In the following days, reporting to the press developments at closed sessions of his Committee, Senator McCarthy said that secret documents had been taken from the laboratories and copies of them had been seen in East Germany, that an important witness had "broken down" and agreed to tell all he knew about espionage, that Fort Monmouth personnel had been linked to known spy rings. Meanwhile the Army announced that it was suspending a number of Monmouth employees "for security reasons."

Independent investigations by newspapermen and others soon began to suggest that the charges and headlines had not conveyed an entirely accurate picture of the situation at Fort Monmouth. The Scientists' Committee on Loyalty and Security, associated with the Federation of American Scientists, thereupon undertook a study of the facts. The chief function of this group is to provide information and advice on government loyalty and security regulations, especially as they affect individual scientists. Most of the members of the Committee at present are scientists at Yale University.

The Committee has interviewed some of the accused Fort Monmouth employees and heard from about 80 per cent of the group by way of a questionnaire, has obtained from the attorneys all the charges against those suspended, together with their answering affidavits, has talkéd with some officials and non-implicated scientists at Monmouth, and has collected information on the work of the laboratories, insofar as information was available outside secrecy restrictions. This article, written by the chairman and the secretary of the Committee, is a brief summary of its report.

The Committee wishes to emphasize that it was concerned in this study with the positive as well as the negative side of security. The long-range military security of the U. S. depends upon both (1) a strong program of research for national defense and (2) protection of that research against the possibility of damage or betrayal of the nation's interests. To maintain an effective balance between these two requirements and at the same time safeguard the rights of individuals is the difficult and unenviable task of security officers and hearing boards. In the Fort Monmouth case we have sought to evaluate the net results of the investigations; in other words, to compare the possible gains in security through the removal of doubtful personnel with the disruptive effect of the investigations on the output—present and future—of these laboratories.

The Signal Corps Engineering Laboratories at Fort Monmouth make up a large complex which serves as the center for the Army's electronics research and development. It is concerned with communications, radar, fire-control equipment, defense against radiological warfare, control of guided missiles and so on —essentially its main function is to develop means for defense of the nation against attack, particularly air attack. Spending some $75 million a year, the SCEL carries on about 450 research projects in its own laboratories and contracts for about 700 outside. It has a professional staff of some 1,300 scientists, engineers and technicians, and three working divisions: the Squier Signal Laboratory, which translates military requirements into scientific concepts and develops components for electronic equipment; the Coles Signal Laboratory, which concentrates on the field of communications; and the Evans Signal Laboratory, which does research in the physical sciences and develops radar and countermeasures equipment.

It was in this busy, vital establishment that the bombshell exploded last October. Let us first examine the charges made and the replies to them. In this brief article we cannot, of course, do more than give a digest of our findings.

Senator McCarthy charged that two persons had invoked the Fifth Amendment and refused to answer questions about Communist or espionage activities. Neither of these individuals, it has developed, was connected with the Fort

Monmouth laboratories: one worked for a private laboratory which may have had a subcontract, the other was accused of having made a large number of telephone calls to government installations, including Monmouth.

The McCarthy Subcommittee charged that Aaron Coleman, a section chief at the Evans Signal Laboratory, "had been recruited into the Young Communist League by Julius Rosenberg, the atom spy, and had been caught with secret radar documents taken from the Laboratory by him, and found in his room when searched by Army investigators in 1946." Coleman has stated in a sworn affidavit that Rosenberg persuaded him to attend a meeting of the Young Communist League at the City College of New York in 1937 but that the meeting served only to make him more anti-Communist. He declares that all but two of the 43 documents he took home in 1946 had been declassified and that he was merely using them for overtime work for the Laboratory. He was also charged with associating with the convicted spy Morton Sobell; he replies that his contacts with Sobell had been limited to college and business and that he was not aware of Sobell's Communist sympathies. Coleman, who received a commendation for his part in developing "some of the most important radar sets used during World War II," affirms his loyalty to the U. S. in the strongest possible terms.

Another seriously accused was Hans Inslerman. He was charged with association with his brother, Felix Inslerman, who was admittedly a photographer for the Communist Party underground in 1937-1938, and with having been a Communist affiliate in 1933. Hans believes that the registration record produced is a forgery, vigorously denies ever having been affiliated with the Communist Party and says that he has had very few contacts with his brother since 1936. He points out that he was investigated in 1950 and then restored to clearance for secret work.

Senator McCarthy charged that a Monmouth employee was cleared by the Laboratory "despite proof of his disbelief in our form of government and proof that within the secret radar laboratory at Fort Monmouth he had been distributing pamphlets calling for the end to our military effort." The proof of his "disbelief in our form of government" was that he was said to have spoken favorably of conditions in the U.S.S.R. The employee in question denies that he made such statements and says that the pamphlet was a Quaker brochure opposing universal military conscription and that he gave copies only to several interested friends.

Regarding the witness who "broke down" at a McCarthy Subcommittee hearing, it developed that his mother had died two days before the hearing and he had been upset by the rapid barrage of questions. He denies that he lied at any time or knew of any espionage and declares he has always been a loyal American. He had a nodding acquaintance with Rosenberg and Sobell.

The McCarthy Subcommittee said that "over 20 witnesses connected in various ways with the radar establishments invoked the Fifth Amendment." The phrase "connected in various ways with the radar establishments" was, to say the least, used rather loosely. Seven former Monmouth employees did invoke the Fifth Amendment, but according to all available information none of them had been employed there after 1947. The possibility that there may have been espionage at Monmouth during World War II is not excluded; the question that has disturbed the laboratories and is at issue today, however, is the charge of current or recent espionage. We must note that none of the present or recent Monmouth employees who were questioned has been accused of espionage. None has invoked the Fifth Amendment or in any way refused to cooperate with the Subcommittee or with Army security officers.

These were the main charges of the McCarthy Subcommittee. Apparently influenced by pressure from that Committee the Army suspended or withdrew clearance from close to 50 persons at Fort Monmouth. As we write this article, some 21 employees are still under suspension and being examined by a security review board. About 25 others are working at Monmouth but without clearance to classified work. Many were first suspended and then reinstated without clearance. A number of them are employed in an unclassified area which they have named "the leper colony." They have received no formal charges, and under present regulations can take no formal steps to resolve their cases. All but a small proportion of the charges against the suspended employees have to do with their associations, either with individuals or with organizations. Five are accused of associating with their wives, three with in-laws, 11 with blood relatives. One man is charged with maintaining a continuing association with his father, against whom 10 items of suspicion are listed. The son declares that he was not influenced by his father's views and affirms his own loyalty. Two brothers are charged with associating with each other; one is accused of attending a rally at which Paul Robeson spoke, of signing a Workers' Party petition in 1940 and of listing as a reference a man whose name appears on the mailing lists of two organizations cited by the Attorney General as Communist; the other is charged with favoring the "leftist" policies of newspaper columnist Max Lerner and with listing as a reference a man who was reportedly a member of the Young Communist League. Both brothers deny the charges. Another man is accused of having attended Communist meetings in the 1930s; he states that he was taken to them by his mother when he was 12 or 13 years old, that he disagrees completely with his mother's political views and has not seen her for the last four or five years.

In general the accused individuals' answers, presented in sworn affidavits involving heavy penalties if proved false, range from flat denial to admission of the charges but denial of the implications drawn. It is significant that no charges of espionage have been made. The only charges that raise any threat of dangerous connections with espionage activities have been denied under oath. Almost

EDITOR'S NOTE

John B. Phelps is secretary of the Scientists' Committee on Loyalty and Security; Ernest C. Pollard is chairman. The Committee is sponsored by the Federation of American Scientists. The members of the Committee are: L. C. Biedenharn, Ralph S. Brown, Jr., Earle C. Fowler, Hans Graetzer, Mark A. Heald, Franklin Hutchinson, G. E. Hutchinson, H. L. Kraybill, John K. Major, Waldo Rall and J. M. Sturtevant, all of Yale University; S. A. Goudsmit of Brookhaven National Laboratory and Hugh C. Wolfe of Cooper Union. A copy of their full report may be obtained for 50 cents from the Scientists' Committee on Loyalty and Security, 2153 Yale Station, New Haven 11, Conn.

uniformly the employees' answers deny or explain any implications of risk created by the charges.

Our Committee could not help being struck by the heavy reliance of the charges on organizational affiliations, which for the most part are as open to innocent as to harmful inferences, and on associations with individuals, from which again different inferences can be made.

There is strong reason to believe that the Army's formal charges were drawn up hastily and under pressure, and this seems to raise some doubts as to the competence of those responsible for maintaining security. The suspensions and losses of clearance showed a large spurt at the time of Senator McCarthy's investigation. The commanding general at Fort Monmouth made no attempt to refute the unsupported charges of espionage. However, the Army hearing board considering the cases of the suspended employees has conducted the hearings fairly and thoroughly, according to all reports reaching us.

We consider next the effects of the investigations on the work of the Signal Corps Engineering Laboratories. A large percentage of the 45 or more accused individuals were key personnel; 15 of them were at the level of section chief or higher, and altogether they supervised some 600 employees—about one seventh of the entire civilian force. In the Evans Signal Laboratory seven out of a total of 29 section chiefs were removed. The average age of the penalized professionals was 37 years, their average salary about $7,400 and their average Civil Service ranking 11 (on a scale of 18), which places them in the supervisory group. It is especially interesting to note that their average length of service at the Laboratories was more than 10 years. The "average" employee went to SCEL in his late 20s and has remained there since World War II, in a period when many scientists and engineers have changed jobs frequently. He has spent more than two thirds of his professional life in the service of the Signal Corps. The majority have apparently been satisfied in their work and obviously are not "misfits" who might tend to be unreliable or perhaps unsuited for highly classified work.

Of those who responded to our questionnaire or were reached by personal interview, 29 were concerned with some phase of electronics, and several were making contributions to basic research in physics (no doubt with some practical military application in view). Fourteen were concerned with radar research and development, and 10 were doing work which contributed more or less directly to defense against enemy air attack.

It is clear, especially to scientists, that the removal of a key engineer or a senior scientist who carries the main responsibility for a project will almost invariably cripple that project. This may be especially true in a large laboratory with a more or less vertical organization such as the SCEL has. The reports to us indicate that the shifts of personnel did in fact hurt at least 20 projects. Several of those removed were acknowledged to be the "spark plugs" of their projects, and it was generally agreed that their projects were seriously crippled. Some men were not allowed to complete reports on work already finished. A former section chief has been told by friends that his section was left virtually leaderless. Another estimates that about $500,000 has been lost on the projects from which he was removed. One employee held the responsibility for a large segment of an air-defense project on which some $32 million had been spent.

It should be noted that the individuals we interviewed were generally able to discuss their difficult personal situations calmly, rationally and with a degree of objectivity which seems, under the circumstances, remarkable. Those now working in the "leper colony" and elsewhere without clearance are engaged in a variety of tasks. Some are teaching in the Signal School or preparing textbook material. Others are contributing to their former projects in an advisory capacity. Some are working on minor unclassified projects completely unrelated to their former tasks. A few are engaged in administrative duties which make no use of their technical knowledge. Most of them feel that their talents are poorly utilized; it is safe to say that this highly skilled technical manpower is being largely wasted. As a footnote, the salaries being paid to this group total some $180,000 per year.

Damage to morale is difficult to assess. The Army has publicly stated that the morale of its Monmouth employees suffered as a result of the McCarthy investigation. It is clear that the manner in which the Army itself handled the matter also impaired morale. Men were suspended, reinstated and suspended again within the space of three or four months. The employees deprived of clearance feel helpless to obtain a final determination of their cases. The Fort Monmouth scientists generally agreed that the Army's actions were at times precipitate, unfair, seemingly indecisive and on the whole confusing. All but one scientist felt the damage to morale would be lasting. There was widespread feeling that the Signal Corps had not returned its staff members' loyalty in their time of trouble. A number of employees have already left the SCEL, and others have expressed a desire to leave at some future time when no suspicion is likely to attach to their resignations.

Many of the accused employees have suffered severe personal hardships. Their professional futures are in jeopardy, even for nongovernment employment. Many have had extremely unpleasant experiences as a result of lack of understanding on the part of their fellow employees, their friends and the community in which they live. It seems clear that all this cannot but have its effect upon the morale of the great majority of Monmouth employees.

The Monmouth affair has had wide consequences. Already our Committee has had from students and scientists anxious requests for advice as to whether they should apply for work in government laboratories. It is difficult to advise them with any confidence, for there is no assurance that similar interference may not occur at other defense laboratories and perhaps in industries working on military projects. The present security regulations in operation are manifestly failing to safeguard the positive aspects of security.

The Monmouth case, it seems to us, points the lesson that, at the very minimum, security procedures should be revised so that suspensions, when they are necessary, are supported by charges carefully drawn by competent security officers free from outside pressures; that an accused person may be promptly heard; that once he is cleared the decision should be binding for at least two or three years unless new information clearly derogatory to him develops. Beyond that, we suggest that the President should appoint a high-level committee of scientists and administrators to study not only the Fort Monmouth situation but the whole present security setup. The events at Monmouth accentuated a security trend which is dangerous to the nation. In the words of John Stuart Mill:

". . . a State which dwarfs its men, in order that they be more docile instruments in its hands even for beneficial purposes, will find that with small men no great thing can really be accomplished."

HURRICANES

By flying through furious winds into the calm, clear "eye" of these vast storms, meteorologists are beginning to learn something of their complex origins, structure and behavior

by R. H. Simpson

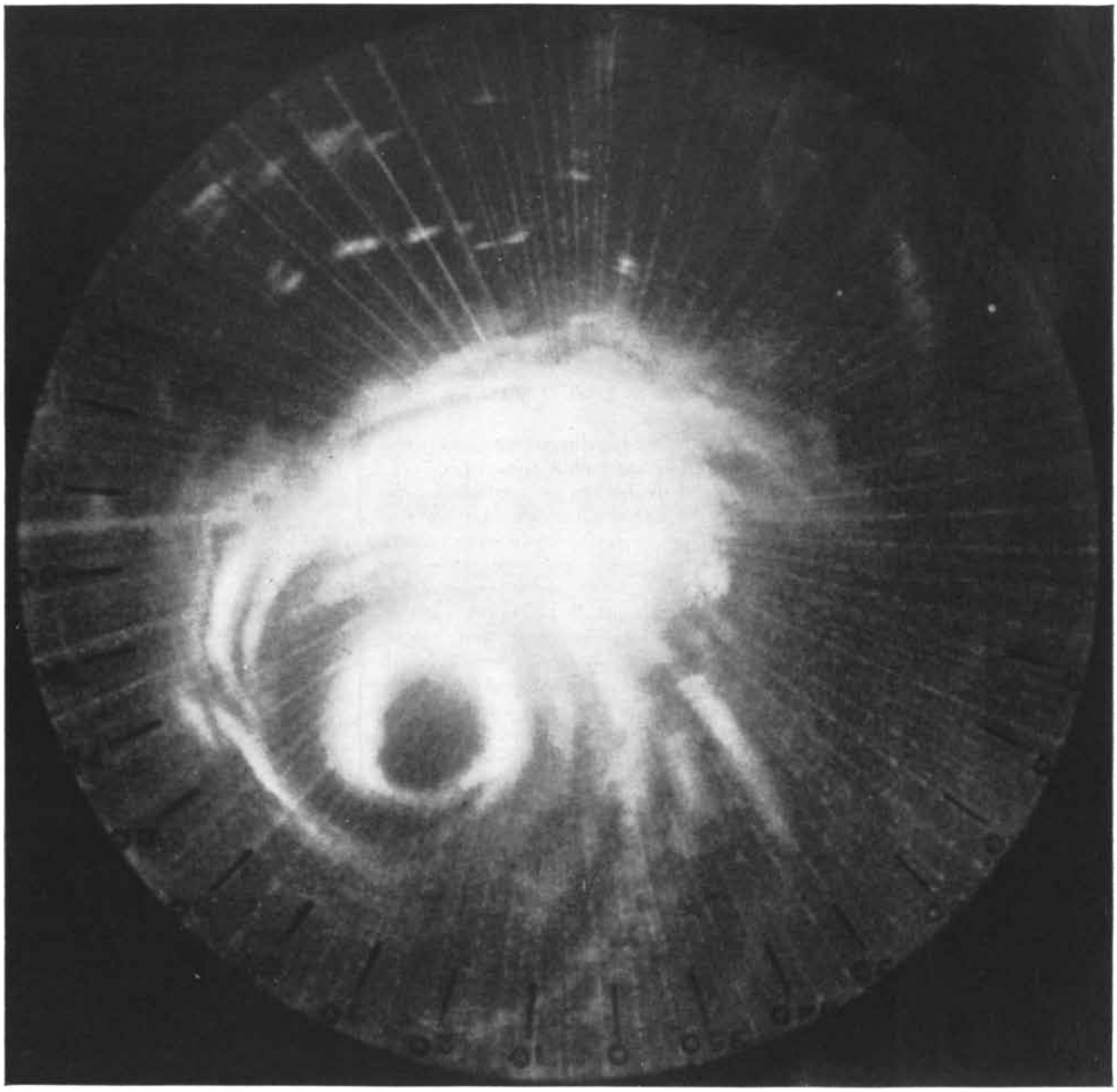
A hurricane is the most dangerous and destructive of all storms on the earth. It does not cover nearly as large an area as the ordinary storms that make our week-to-week weather, nor can it match the concentrated fury of a tornado, but it combines violence and sweep to spread devastation over a huge path. The vortex of a hurricane may cover more than half a million square miles, and its winds may reach 150 miles an hour or more. Sometimes it generates a whole rash of tornadoes on its fringes. What makes a hurricane most dangerous is not primarily the wind, however, but the great waves which it may pile up in the sea. As recently as 1935 a hurricane wave drowned or killed more than 400 persons in the Florida Keys; in 1900 the wave at Galveston drowned more than 6,000; and in India in 1876 a hurricane produced an inundation in which more than 100,000 people perished.

The hurricane phenomenon itself is known by various names: in the China seas it may be called a typhoon or baguio, in Australia a willy-willy, in India a Bengal cyclone. Except that the typhoons of the western Pacific may reach a bigger size than the others, because they sweep over vast expanses of warm water, all these phenomena are the same —cyclones which arise over tropical seas and grow to incredible energies. A mature hurricane spends kinetic energy at the rate of 500 trillion horsepower, the equivalent of several thousand atomic bombs per second! How does it develop such appalling power?

There used to be a rather simple theory about how cyclones developed: In the calm, moist air of the tropical doldrums an eddy of warm air begins to rise, and as it rises, air rushes in at the bottom to replace it. The air currents are given a counterclockwise motion (in the Northern Hemisphere) by the rotation of the earth—the Coriolis effect. This cyclonic circulation becomes the nucleus of a hurricane. The main shortcoming of the theory was that it failed to explain why the eddy began in the first place and why the air went on rising at an accelerating pace in the center of the cyclone. If the speed of circulation is to increase and the cyclone is to grow in intensity, the rising air must be carried rapidly away from the center to reduce the pressure so that air can rush in with increasing velocity at the bottom. How this could happen was a puzzle. We have learned, indeed, that the answer to the question holds the key to the formation and growth of hurricanes.

SURFACE OF THE SEA about 60 miles from the center of typhoon "Marge" was photographed from an airplane flying at 1,700 feet. The wind was from 75 to 85 miles per hour.

A decade ago meteorologists began to collect detailed information about the structure of the hurricane core—at first with radiosonde balloons and later with radar and by direct airplane flights into the "eye" of the storm as well. The first sounding was made at Tampa, Fla., in 1944; the radiosonde balloon rose to 56,000 feet in the eye of the hurricane, and its tiny radio transmitted back a continuous record of the temperature, pressure and humidity conditions at various levels of the cyclone core. In 1947 the writer, along with members of the Air Weather Service, made several reconnaissance flights into the eye of the



RADAR SCOPE shows the spiral structure of a hurricane. The eye is at lower left. The radar set picks up rain squalls, which follow closely the pattern of the winds. When this photograph was taken, the eye was 37 miles away. Visibility was an eighth of a mile.

Atlantic hurricane "George," and again in 1951 we flew into the Pacific typhoon "Marge"—the third largest hurricane on record.

For the latter flight we took off from Guam at dawn on August 15, 1951. The typhoon center was 700 miles away. Flying at 11,000 feet, we were below a dull overcast, part of the shield of high clouds with which Marge had surrounded herself. As we approached the storm, we could see long swells in the ocean coming from the hurricane's direction—remnants of the enormous waves generated at its center. There was an ominous absence of random clouds beneath the solid overcast; they had all been marshaled into great streamers or "squall lines" which, as we could see on the radar screen, were spiraling in around the eye of the typhoon.

As we came closer, the surface winds grew stronger. Two hundred miles from the center they reached hurricane force—74 miles per hour—and in another 50 miles they had increased to 100 miles per hour. From here on we could no longer see the surface, for the cloud cover now engulfed the plane completely. Only the spiral pattern of the squall lines on the radar screen enabled us to keep headed toward the storm center. Soon the edge of the rainless eye became visible on the screen. The plane flew through bursts of torrential rain and several turbulent bumps. Then, suddenly, we were in dazzling sunlight and bright, blue sky.

Around us was an awesome display. Marge's eye was a clear space 40 miles in diameter surrounded by a coliseum of clouds whose walls on one side rose vertically and on the other were banked like the galleries in a great opera house. The upper rim, about 35,000 feet high, was rounded off smoothly against a background of blue sky. Below us was a floor of low clouds rising to a dome 8,000 feet

above sea level in the center. There were breaks in it which gave us glimpses of the surface of the ocean. In the vortex around the eye the sea was a scene of unimaginably violent, churning water.

For four and a half hours we cruised in the eye of the typhoon, taking observations and making photographs of the clouds. Among the most significant measurements were those of temperature. We found the air in the eye considerably warmer than that in the surrounding vortex. At 8,000 feet its temperature was some 14 degrees Fahrenheit higher; at 18,000 feet the eye temperature was more than 32 degrees higher than that of the outer fringes of the vortex. This astounding temperature gradient indicated that the storm had as great a concentration of potential energy as has ever been detected in the atmosphere.

A hurricane can be regarded as a gigantic heat engine fueled by the latent heat released by water vapor condensing in the air. Its nucleus usually springs from a turbulent eddy in the trade winds, not necessarily in the doldrums ["Trade-Wind Clouds," by Joanne Starr Malkus; SCIENTIFIC AMERICAN, November 1953]. The hurricane develops when the wind pattern aloft, about whose nature there is some doubt, removes the rising air at upper levels.

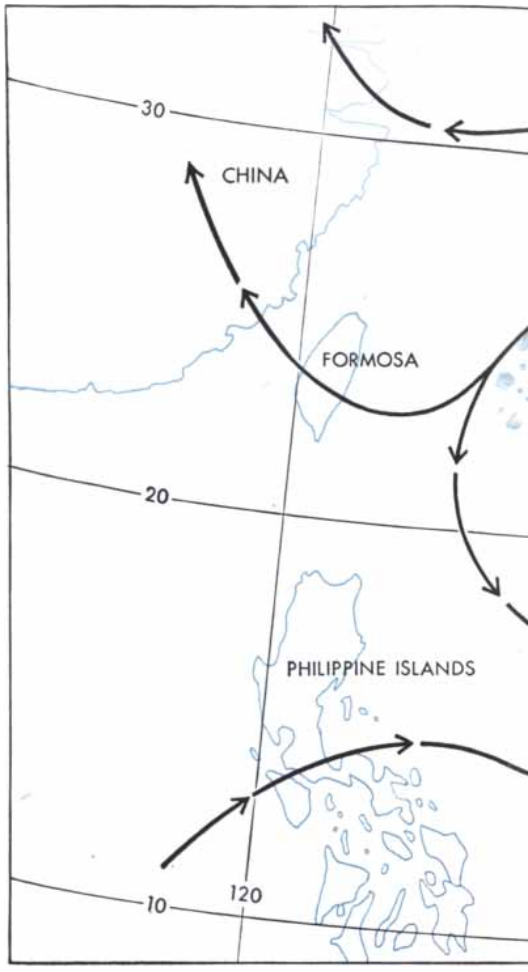
Any storm must have a low-pressure center to maintain its circulation. In a hurricane the air pressure at the center of the storm may be as much as 10 per cent lower than at the edge. Moreover, most of this pressure gradient usually occurs within 30 to 40 miles of the core. The greatest fury of the cyclonic winds is concentrated in the region near the eye; in a small but violent storm the maximum winds may be within a few hundred yards of the eye, while in a mature hurricane they are several miles away. The highest wind velocity ever measured at the surface in a hurricane was 186 miles per hour, recorded at the Mount Washington weather observatory during the New England storm of 1938.

The surface winds spiraling around the eye force moist air violently upward at a rate which may exceed a million tons per second. As this air is cooled, its moisture is condensed and wrung out in the form of rain. The condensation releases vast quantities of latent heat, raising the temperature near the eye considerably above that of surrounding areas. Pressure decreases with height less rapidly in warm air than in cool. Consequently at higher altitude the pressure gradient between the inner and outer parts of the vortex becomes smaller. As a result the spiraling currents of air, because of their centrifugal force, fly outward. This is how air leaves the center and prevents the storm from decaying. The process is reinforced by the so-called solenoid effect, which has the result of converting potential energy into kinetic energy and accelerating the outward flow of air.

As for the primary source of the hurricane's energy—the inrushing moist air—there can be little doubt that all of it comes from near the surface of the sea. Unlike a thunderstorm or large cumulus cloud, the hurricane entrains little or no air from its surroundings at levels above 2,000 or 3,000 feet from the surface.

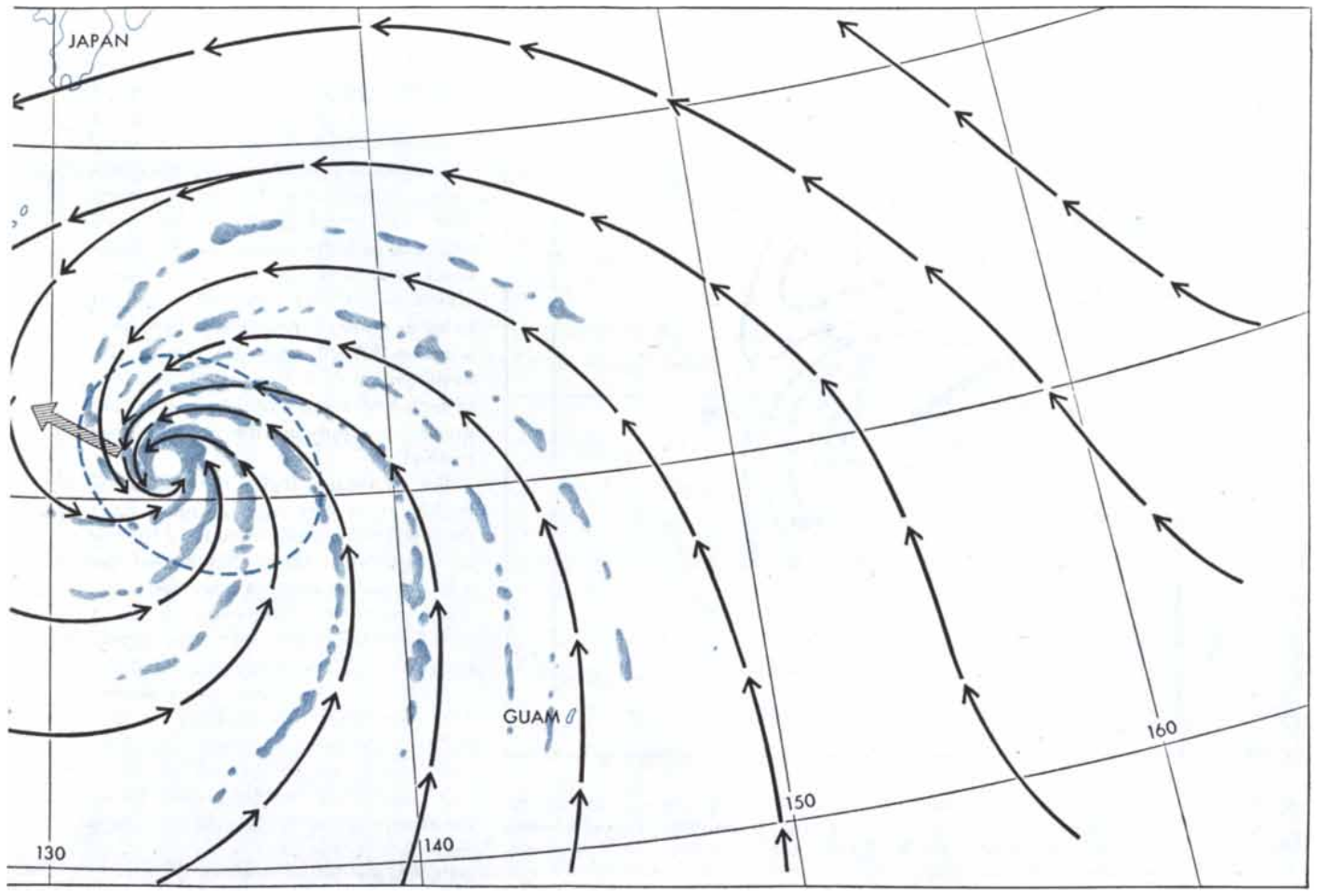
So far we have been considering only the lower and middle layers of the vortex. At the bottom air moves in; at intermediate levels it moves out. But at the top other air pours into the storm center. Our observations in the Marge reconnaissance flight showed that most of the air filling the middle and upper layers of the eye had descended from great heights, probably having been injected at some point near the top of the storm's cloud system. The great warmth of the eye stemmed mainly from compression of this air, brought down from high levels, rather than from the condensation of water vapor. On the other hand, the existence of the cloud floor at the bottom of the eye means that some turbulent air must seep into the eye near the water surface. If air is introduced simultaneously both at the top and the bottom of the eye, there must be outflow at intermediate levels; otherwise the pressure at the center would rise and the storm would decay. This circulation downward and outward from the eye is in exactly the opposite sense, with respect to the surfaces of equal entropy, to that of the major circulation surrounding the eye, and hence absorbs kinetic energy. It therefore tends to act as a governor, braking or retarding the fury of the storm.

Perhaps the greatest enigma of hurricane structure is the way the heavy rains are concentrated in great spiraling squall lines. These lines were discovered by radar, which makes it possible to watch the rainbands and the storm center itself from distances up to 300 miles. A small, immature hurricane sometimes concentrates most of its rain around a single rainband, which spirals inward toward low pressure like a huge comma, entwining itself around the eye. A more mature storm contains a number of spiral

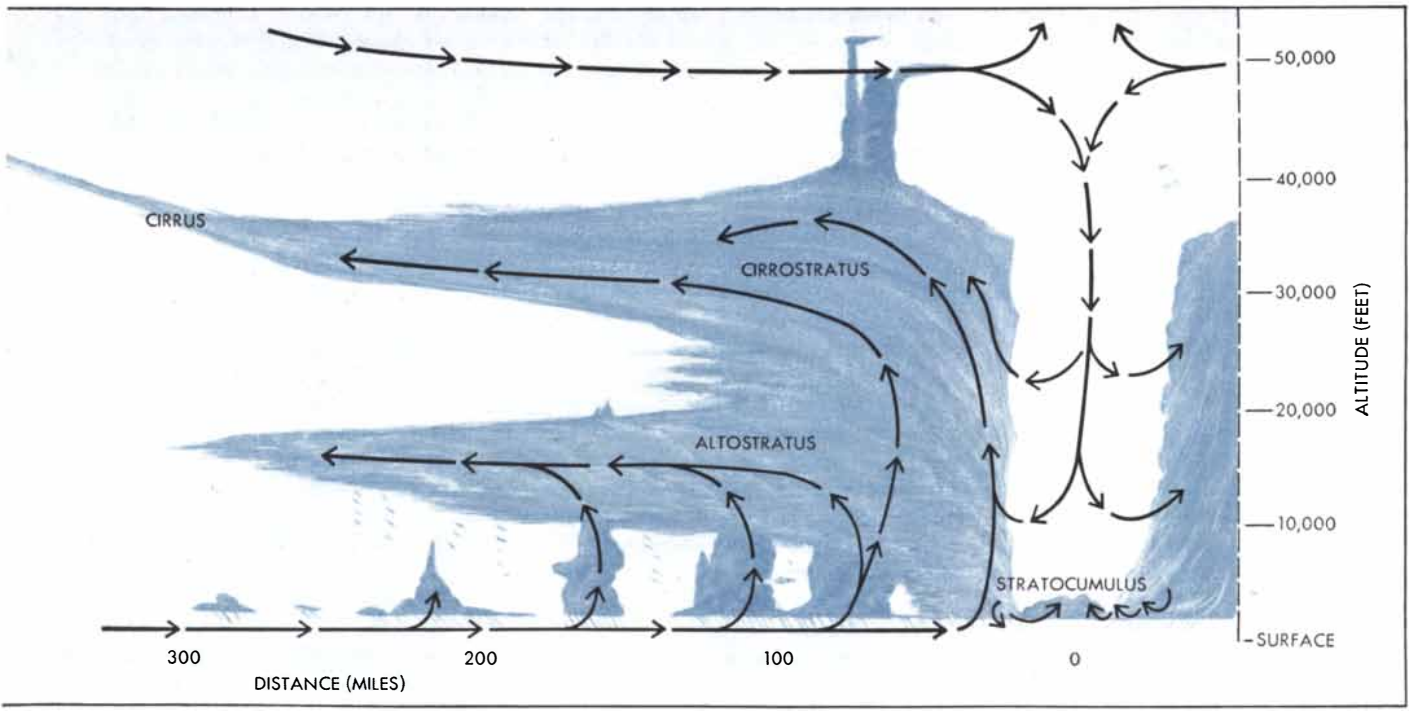


TYPHOON MARGE exhibits the typical spiral wind pattern (*black arrows*) of a ma-

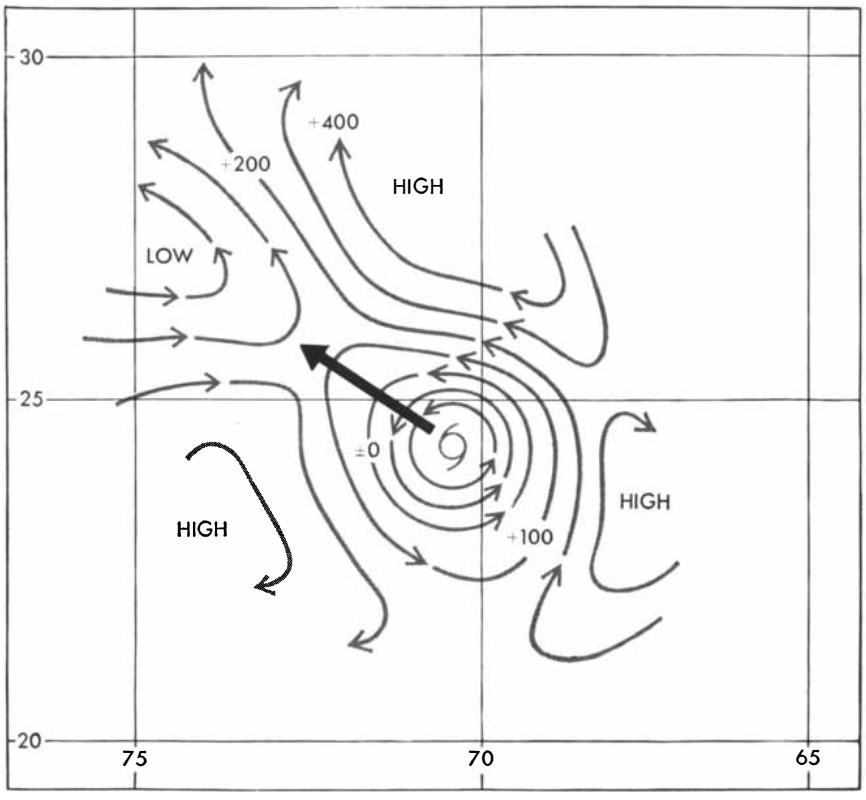
CROSS SECTION of an ideal hurricane shows the circulation of air in the vortex.



ture tropical cyclone. Almost parallel with the air currents are bands of rain clouds, converging with the winds around the small, clear eye. The rain clouds make the storm visible on radar. The large cross-hatched arrow shows where the storm center is heading.



Warm, moist surface air converges around the eye and is forced upward, releasing large amounts of heat through condensation. This heat is the storm's principal source of energy. Air also enters from the top. At intermediate heights it flows away from the vortex.



AIR CIRCULATION near the top of hurricane "George" was traced by an airplane flying through it. The contours are "D values," or altimeter corrections. The coordinates are degrees of longitude and latitude. The black arrow shows the direction of the storm.

rainbands. For example, in typhoon Marge at least six rainbands were observed. These rain clouds, often visible from an airplane, are rarely detectable from the surface in good perspective because small clouds cluster around and obscure them.

As a hurricane approaches, a succession of squalls usually occur, each associated with one of these rainbands. With each squall the gusts of wind increase in violence, and heavy bursts of rain fall. Each successive squall is more severe than the last, until finally wind and rain become continuous at a sustained peak in the last stage before the eye arrives.

Harry Wexler, Weather Bureau meteorologist, has suggested that the rainbands are, in effect, a manifestation of certain parallel lines of small cumulus clouds which are frequently observed over tropical ocean areas. He reasons that these bands are drawn into the vortex of a hurricane, where a few of them grow at the expense of others.

A mature hurricane usually thrusts forward a curious tongue of warm air in the direction of its movement. The reason for the protrusion of this tongue, first observed by the writer in 1946, is not completely clear. It probably develops in the following way. In the moving storm the greatest piling up of air, and hence the greatest release of latent heat, occurs to the right of the line of the storm's advance. As a result, the horizontal pressure gradient tends to decrease with height more rapidly in this sector than elsewhere. The spiraling streams of air rising in this sector therefore find less resistance to outward movement, and they tend to move tangentially along the line of the storm's path. The vanguard of warm air tends to reduce the pressure ahead of the storm center and contributes to its movement. The warm tongue is not always a reliable indicator of direction; even in mature storms it occasionally shows a tendency to branch into a double tongue at some distance from the center. But as we learn to understand it better, it should help considerably to predict the path a hurricane will take.

The circulation of winds at very high levels remains somewhat mysterious. This is unfortunate because the application of certain hurricane forecasting methods depends upon accurate analysis of wind circulations near the top of the storm. Grady Norton, chief forecaster at the Miami Hurricane Center, has successfully applied a theory that the speed and direction of a hurricane's forward movement can be gauged by the wind velocity at a certain high level where the cyclonic circulation shrivels to a minimum size or disappears. This level, which he calls the "steering level," varies considerably from day to day, for reasons which are not always clear. It is difficult to locate when observations of high-level winds in the storm area are lacking. The development of a more accurate model of high-level wind circulations will help greatly in applying the steering-level method.

Reconnaissance flights and radiosonde soundings at very high altitudes have disclosed two curious features of the top of a hurricane. Above 20,000 feet the relative temperature of the warm eye drops, and there is some evidence that at high levels the core may become slightly cooler than its surroundings, so that the cyclonic winds may tend to regenerate. This possibility was explored in two flights into hurricane George in 1947, and it was found that at 38,000 feet there was a small core of cyclonic winds blowing at approximately 120 miles per hour. Surrounding this core were three small cells of higher pressure which apparently were circulating in the anticyclonic sense.

The other peculiar feature is a trough of low pressure that seems to extend ahead of the storm, becoming pronounced about 300 to 500 miles in advance of it. The trough is very high—at 50,000 feet or above—and no trace of it is detectable below about 20,000 feet. It is beneath this trough that the showers and thunderstorms which herald an approaching hurricane develop. Long, silken filaments of cirrus clouds also stream out in advance of the hurricane center. This cirrus, covering a wide area ahead and to the right of the storm, is probably the best-known precursor of a hurricane. It accounts for the fiery sunset that we sometimes see during a hurricane approach.

The part that the high-level circulation features play in the development and career of a hurricane remains obscure —a real challenge to investigators. The three Rs of hurricane investigation—radiosonde, radar and reconnaissance by plane—have turned up almost as many questions as they have answered. Already, however, they have made possible more accurate, effective and timely warning of hurricanes and substantially reduced the loss of life and of property.

MARGE'S EYE is pictured from a point just west of the storm center, looking southwest, at an elevation of 17,000 feet. The walls rise to a height of almost 35,000 feet. Their upper rim is 40 miles in diameter. Below can be seen a part of the cloud floor.

Insect Control and the Balance of Nature

The common alfalfa caterpillar provides a good example of how a pest may be controlled not only with insecticides but also by manipulating the ecological system of which it is a part

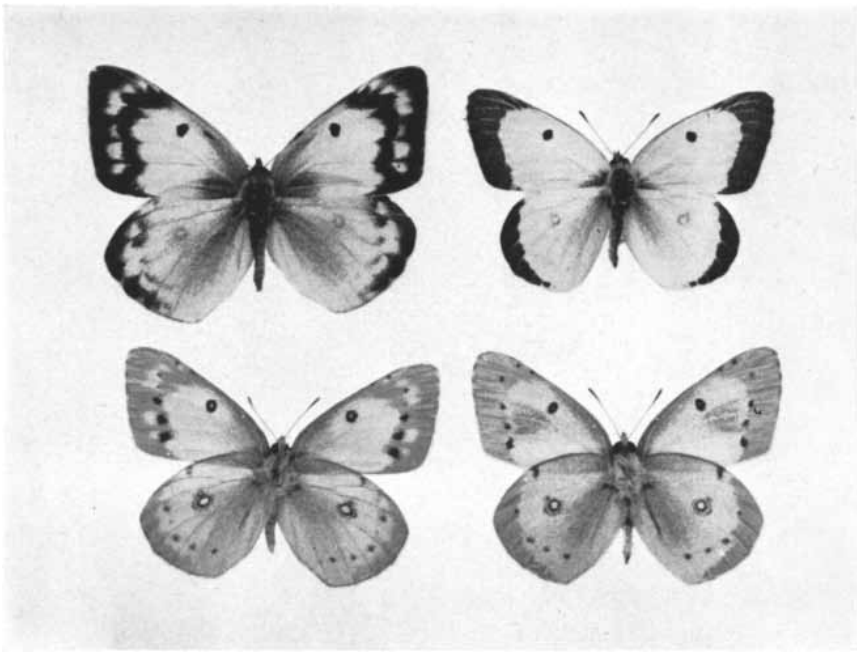
by Ray F. Smith and William W. Allen

The activities of man are continually making changes in what has so inappropriately been called "the balance of nature." He has cleared the forest, plowed the plain, changed the courses of rivers, bred new plants and animals, introduced plants and animals into new areas, protected some from competition and provided others with new foods on which to flourish. For instance, the Colorado potato beetle, once an insignificant insect feeding on wild herbs in the Rocky Mountain region, has grown abundant on the cultivated potato.

Even in the absence of man, however, the balance of nature is a dynamic and ever-changing system. The relative numbers of the various kinds of plants and animals in the simplest natural community fluctuate constantly in accord with a complex web of interactions that ties them together. Under normal conditions the system as a whole tends to be self-regulating. Such factors as parasites, predators, disease, food supply and the competition for shelter keep any one organism from upsetting the balance. If man is to make a move that will shift the balance in his favor, he must understand all of the ramifications of the system.

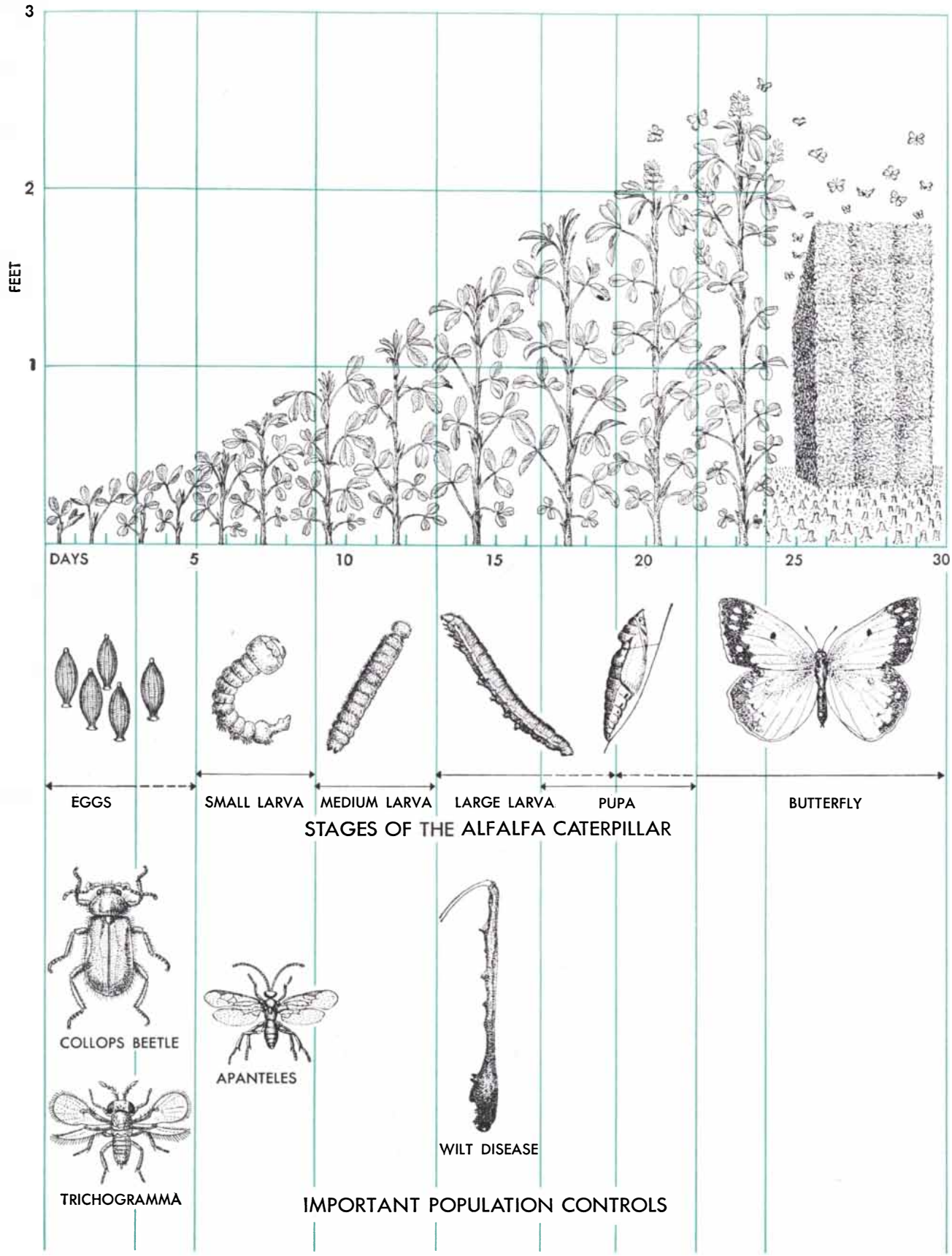
Thus control of insect pests cannot be assured simply by inventing new and more potent insecticides. Our spectacular new chemical weapons have added immeasurably to the welfare of mankind. But they have also created new problems of their own; witness the phenomenal increase of destructive mites that has followed the slaughter of their insect enemies with DDT and other new insecticides, and the rise of new strains of insects resistant to the poisons. Chemical control is at best temporary. If we are to escape this ever tightening spiral of more complex problems and ever increasing costs of control, then we must integrate chemical control with the natural factors influencing populations.

For progress in this direction in recent years we are indebted to the science of ecology. This is the study of the interrelationships of organisms and their environment. We shall here recount such a study of an insect, carried out during the past 15 years in California, which will illustrate how complex these relationships can be. The insect is the orange alfalfa caterpillar, *Colias philodice eurytheme*.

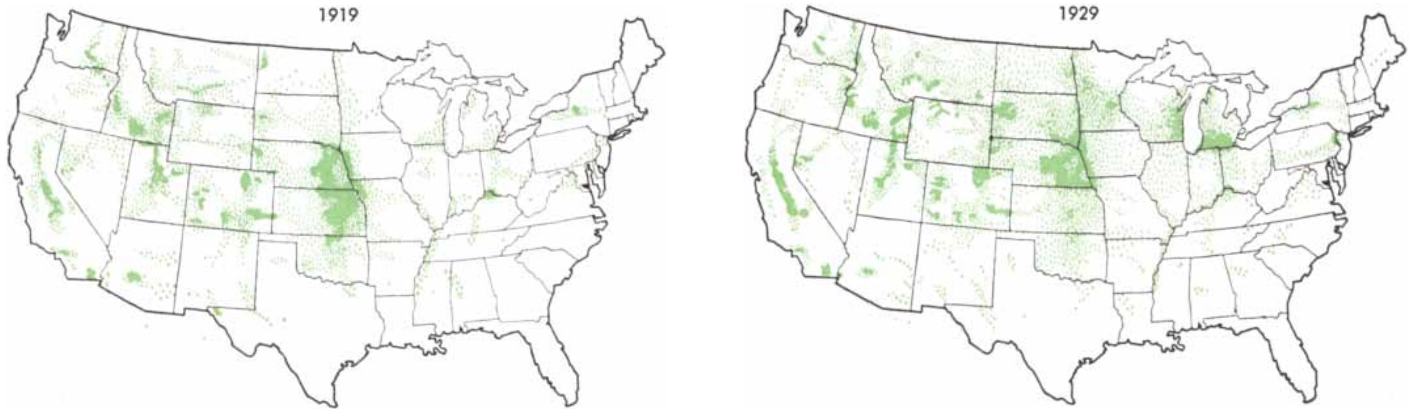


BUTTERFLIES of the alfalfa caterpillar are shown actual size. At the upper left is the female of the species from above; at the lower left, the same individual from the bottom. At the upper right is the male; at the lower right, the same individual from the bottom.

In its adult form the insect is the common orange and yellow butterfly seen flitting about alfalfa and clover fields in summer. In alfalfa-growing sections of the country the butterflies often are so abundant that they clog the radiator



STAGES of the alfalfa caterpillar (*middle*) are geared to the growth and harvest of alfalfa (*top*). The important population controls of the caterpillar (*bottom*) are the *Collops* beetle and the wasp *Trichogramma minutum*, which eat its eggs; the wasp *Apanteles medicaginis*, which lays eggs in its small larvae; and wilt disease, which turns the large larvae into a semiliquid mass.



EASTWARD SPREAD of both alfalfa and the alfalfa caterpillar is indicated by these maps of the U. S. The map at the far left shows the pattern of alfalfa cultivation in 1919; the map second from the left, the pattern of cultivation in 1929; the map third from the left,

grills of automobiles. The female lays tiny, cigar-shaped eggs on the leaves of young alfalfa. In summer the eggs hatch in about three days; in cooler seasons they take up to 10 days or more. After hatching, the tiny caterpillar eats its egg-shell and then begins to feed on young alfalfa leaves. Three days later it makes its first molt; it sheds its skin four times before it is fully grown. After each molt the caterpillar and its appetite increase in size. By the time it is full-grown it may consume more than a dozen leaves a day. After about 12 days (in hot weather) the caterpillar descends to the base of the plant to pupate. Five or six days later the beautiful butterfly emerges.

During the summer it has two peaks of activity each day. It spends the night near the base of the plant. After sunrise it crawls up the plant and turns its body to receive the maximum radiation from the sun. After its body temperature has warmed up to the necessary level, it takes off in flight. It feeds on flower nectar and stops from time to time to lay eggs. During the heat of midday it siestas in the cool alfalfa or on the moist soil. Then in the afternoon it goes forth again to flit about until the sun sinks.

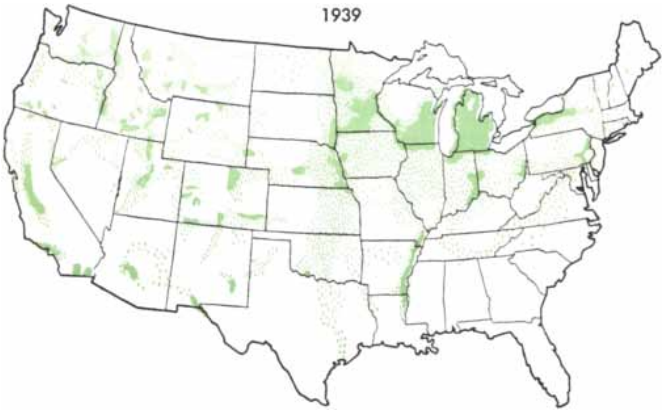
The males spend most of their time seeking young females; the latter mate just after they have emerged from the pupal state. After mating, the female leaves the field in which it developed. To provide its young with proper food, it always lays its eggs on a young, succulent legume. This remarkable adaptation, originally evolved for survival on wild plants, stands the insect in excellent stead in alfalfa fields. Its eggs are laid only on very young alfalfa shoots; as a result the caterpillars can complete their development before the hay is cut.

Because females concentrate for egg-laying in recently cut fields where a new crop is beginning to leaf out, alfalfa fields can be classified according to the stage of development of their caterpillars. First is the egg-laying stage, when the alfalfa is short; the field is populated mainly by egg-laying females. In the second stage, when the alfalfa is less than a third grown, its population is mainly tiny larvae. In the third, when the alfalfa is about half grown and the larvae are bigger, it becomes possible to predict how much damage the population will do and to decide on preventive measures. In the fourth stage, the larvae do much damage to the maturing alfalfa. In the fifth, when the alfalfa is mature or nearly so, the field is full of pupae and butterflies, about three fourths of which are males. Any caterpillars that have not become butterflies when the field is mowed are out of luck—they die in the hot sun.

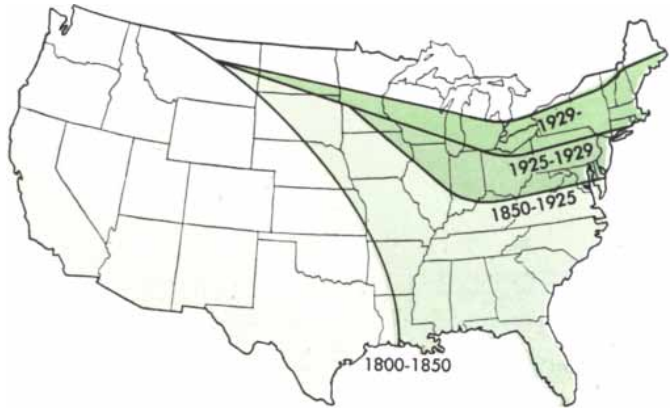
The critical requirements of the alfalfa caterpillar probably are: (1) a sufficient concentration of suitable legumes, (2) a period of warm weather long enough for the development of at least one generation, and (3) suitable places for survival during the unfavorable times of the year. These broad requirements can be met in many different ways, and the alfalfa caterpillar is therefore widespread in the U. S. [*see map on the opposite page*]. Its range changes with the seasons and the year-to-year fluctuations in the weather; for example, the butterflies migrate north in the spring and invade desert areas when rains produce legumes there. In the past few decades the alfalfa caterpillar has expanded tremendously in the Eastern U. S. since Eastern farmers began to lime the soil and grow alfalfa.

A single female butterfly can lay as many as 1,500 eggs. We would soon be smothered by alfalfa caterpillars but for a complex of natural control factors which we do not yet completely understand. The abundance of this insect, like that of any other organism, depends on natality and mortality. These in turn are determined by a complex system of ecological relationships which we call an ecosystem. The ecosystem includes the influences and relationships of all the living and non-living parts of the environment, among which must be counted food supply, weather, natural enemies and the caterpillar population itself. Because of its great complexity it is difficult, if not impossible, to study an ecosystem per se. However, we can study a particular kind of organism in its relationships to the ecosystem. Such a study has revealed some of the factors influencing the abundance of the alfalfa caterpillar.

When the alfalfa caterpillar was first discovered in California about 1850, its population level was much lower than today. It lived on scattered native legumes such as lupine, clover, lotus and locoweed, which are most abundant during the late spring. In summer it was restricted to streams and rivers or the mountains. Now not only its range but its population density has been increased enormously by the growing of alfalfa—today covering more than a million and a half acres in California. Alfalfa and certain cultivated clovers supply it with an abundance of food throughout the year. Furthermore, the concentrated cultivation of alfalfa in fields close together favors the reproduction of the caterpillars. Since the fields are not likely to be in the same stage of growth, the butterflies emerging from one field have a good chance of finding a nearby field which is



the pattern of cultivation in 1939. In the latter year the acreage of alfalfa cut for hay constituted about 20 per cent of the total acreage



of hay. The fourth map shows the spread of the alfalfa caterpillar from 1850 (*lightest green area*) to the present (*darkest green area*).

in the proper stage for egg-laying. Thus a moderate outbreak in one field can result in a severe outbreak in another. This explains why some fields are hard hit while others nearby may be undamaged.

Within a given field the extent of the outbreak and the damage done will, of course, depend upon the growth pattern of the alfalfa, which in turn is influenced by the type of soil, drainage, irrigation methods, rainfall, topography and cultivation. Cool weather greatly affects the egg-laying of the females, since, as cold-blooded animals, they need warmth to become active. The alfalfa caterpillar passes the severest part of the winter as a small larva. In the short summer of the northern parts of its range only one generation can mature; in mild southern climates there may be as many as seven in a year. In the hot Imperial Valley the population peaks in the spring and fall. In the cool coastal areas of California, where it takes more than 40 days for a larva to develop into a butterfly, the insects do not thrive; the alfalfa is not retarded as much as the caterpillars, hence the hay is cut before the butterflies can emerge. If growers were to change to cutting the alfalfa later, the caterpillars probably would become more abundant.

California's San Joaquin Valley is highly favorable to caterpillars. But in that area the density of the caterpillar population itself provides a measure of control by bringing into play what the ecologist calls density-dependent factors. These are factors in which the intensity of effect increases as population density increases. Competition for food is such a factor, but it is not ordinarily important in the regulation of alfalfa caterpillar populations. Here the most important density-dependent factors are the insect's natural enemies. Among them are beetles, dragonflies, viruses and parasitic wasps. The relationships of the alfalfa caterpillar to some of its enemies are summarized in the chart on the next page. The chart, however, does not show the indirect relationship of the alfalfa caterpillar to other organisms. For example, some of its enemies feed on a great many other hosts and are able to maintain their population levels even when the number of alfalfa caterpillars is low. Nor does the chart show the seasonal aspects of the picture. The parasitic wasp *Pterocormus instabilis* is of importance only during the spring months; the virus disease becomes important in late summer.

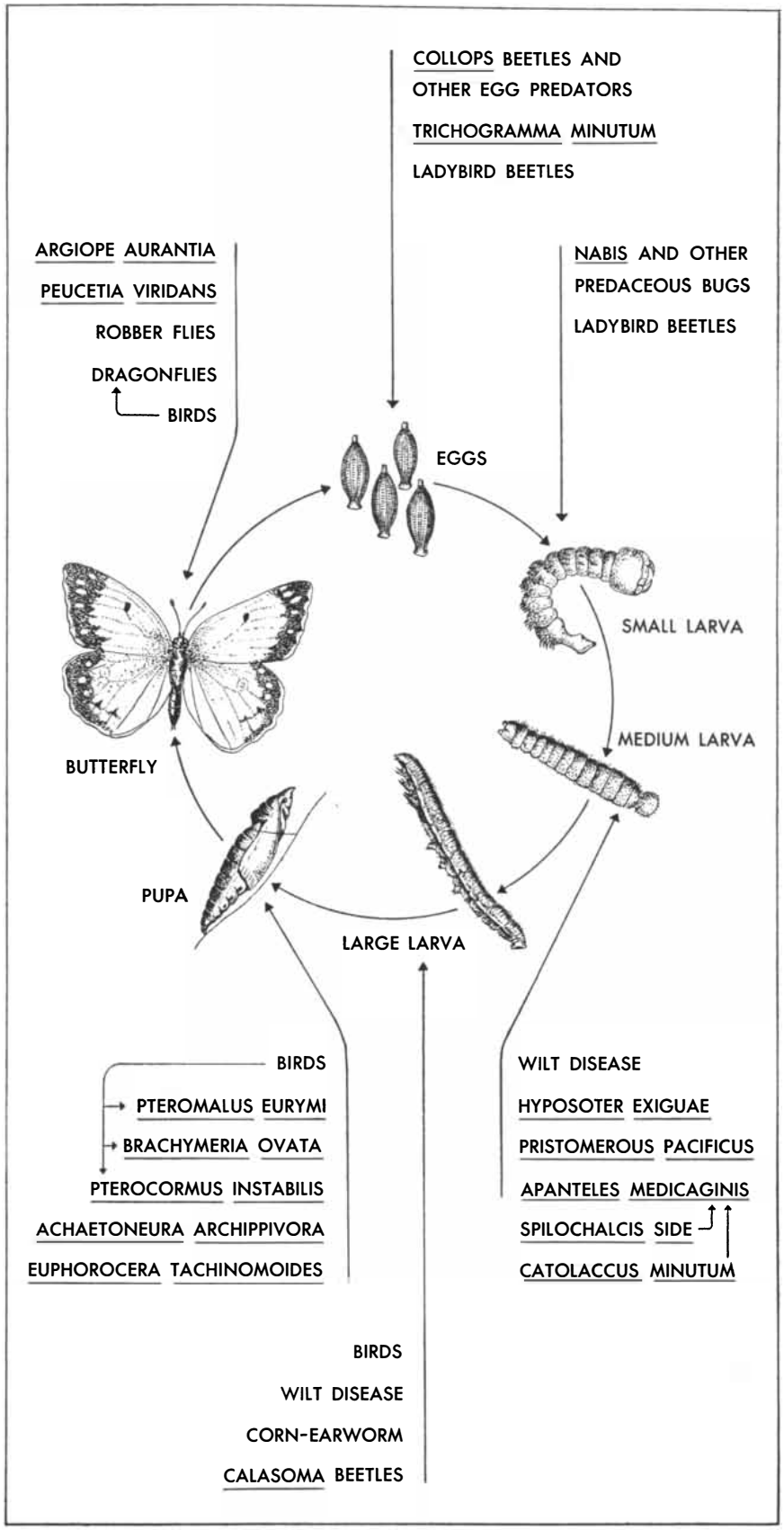
The tiny wasp *Apanteles medicaginis* is one of the most important parasites on the caterpillar population. The female wasp lays an egg in the caterpillar when it is a small larva. When the egg itself hatches into a larva, it feeds in the caterpillar's interior and retards its growth. After about a week the wasp larva emerges from its host and spins a bright yellow or white silken cocoon on the alfalfa leaves. The attacked caterpillar dies. The larvae of this little parasitic wasp are to be found in caterpillars throughout the year. They become more numerous, however, during the summer months when caterpillars are most abundant.

Each year *Apanteles* saves thousands of acres of alfalfa from damage. It has its own requirements, however, which must be met if it is to help farmers. It needs nectar or aphid honeydew as food. Since the wasp, like the caterpillar, must leave the alfalfa fields when they are cut, it can be fully effective only in areas where other food sources are plentiful. Weeds in fence rows and along irrigation ditches can provide it with nourishment.

If *Apanteles* fails to keep the caterpillar population at a low level, the population may be heavily attacked by a virus disease known to farmers as "wilt." The virus, harbored throughout the year in the soil and surface debris, infects the caterpillars only after it has contaminated the alfalfa. After the insects have fed on infected plants, they transmit the virus among themselves. An infected caterpillar soon stops feeding and dies. Then the body breaks down into a semi-liquid mass, which contaminates the surrounding leaves. In this way small foci of wilt develop, and soon the virus becomes widespread in the population. The wilt disease may completely destroy a large population in a few days.

Ordinarily an epizootic of this disease does not occur until the insects have badly damaged the alfalfa. However, one may be initiated artificially by spraying the alfalfa fields with virus when the caterpillars are small. Spraying with a certain bacillus which does not occur naturally in populations of the alfalfa caterpillar also is highly effective against the insect. In the application of these pathogens the proper timing is obviously important.

Let us turn now to the problem of the alfalfa farmer who must decide what to do about the insect situation in his field. It should be apparent from our brief description of some of the many interacting factors that every alfalfa field is a special problem, and the situation must be judged in the light of a complex ecological picture. Farmers know that the infestations vary from field to field and from time to time, and that by the time they have discovered an infestation it is usually too late to do much about it. Furthermore, it does not pay to do gen-



ECOLOGICAL SYSTEM of the alfalfa caterpillar shows not only the creatures that prey on it but also some of the creatures that control the predators. *Trichogramma, Hyposoter, Pristomerous, Apanteles, Spilochalcis, Catolaccus, Pteromalus, Brachymeria* and *Pterocormus* are wasps. *Achaetoneura* and *Euphorocera* are flies. *Argiope* and *Peucetia* are spiders.

eral preventive spraying of hay crops. The farmer needs a way of predicting what will happen in his fields so that he can apply control measures only where necessary.

As an answer to the farmer's dilemma a supervised control system has been developed in California. The farmer, or a group of farmers, hires an entomologist to follow the insect populations in the fields. On the basis of the conditions peculiar to each field and of his knowledge of the ecology of the alfalfa caterpillar, the entomologist makes a prediction early in the growth of the crop as to whether or not economic damage will occur. If the crop is threatened, he may suggest in some situations that the alfalfa be mowed a few days early to avoid damage. The caterpillars on the cut hay will be destroyed by the sun, and the ratio of parasites to caterpillars in the area will be shifted in favor of the parasites. In other cases he may recommend an application of the virus or the bacillus or a combination of the two. Since the timing is critical, they should be applied under supervised control. In still other cases he may prescribe chemical spraying. The insecticide should be one which will not leave any harmful residue on the hay, will not injure the plants, will cause minimum harm to the parasites, and will control the caterpillars economically. Thus far we have no such perfect insecticide; the closest to meeting the requirements are methoxychlor and perthane. Fortunately chemicals harmful to the parasite are not altogether excluded, because they may be used in fields where the caterpillar population is relatively high and the parasite population relatively low. Perhaps not the least of the benefits of the supervised control program to the farmer is the peace of mind he has through the assurance that his fields are under the constant supervision of qualified personnel.

This has been the story of the application of ecological research to the alfalfa caterpillar problem in California. Research is continuing on this problem and further benefits will accrue. The same approach is being made to insect problems in other parts of the world. We have a long way to go to unravel all the strands of this ecosystem of which man is a part. However, we are now in a position to take more intelligent steps toward an integrated control program which will utilize all the resources of ecology and give us the most permanent, satisfactory and economical insect control that is possible.

Kodak reports to laboratories on:

getting ready for an astronomical event... a new idea in photographic emulsion making... an instrument that makes microprint reading a pleasure... keeping bronzing lacquers from gelling

Eclipse

A gentleman has suggested we capitalize on the total solar eclipse of June 30, 1954 by giving away viewers which he can sell us at one cent apiece in quantities of 350,000. We are turning him down.

Instead, we are celebrating the eclipse in our own way by offering (also free of charge) a set of notes embodying our technical recommendations on solar eclipse photography. It tells in what combinations of film, shutter and diaphragm settings, and Kodak Wratten Neutral Density Filters we think your best chances lie of recording the phases, the flash spectrum, the inner corona, the landscape during totality, and (if one is very lucky) the shadow bands.

For those who will be fired with persistent photographic ambitions on that great Wednesday morning, we are ready with a textbook on astronomical photography as the professionals know it. *Photography in Astronomy* is authoritative, explicit, practical, and light enough for a baby to hold in one hand.

Wire Eastman Kodak Company, Industrial Photographic Division, Rochester 4, N. Y., for the notes if the date seems too close for the mails. The book can be ordered from your Kodak dealer whenever the fancy strikes.

Royal Pan

Once in a while the orderly flow of progress in photographic technology makes a gush, and then you have something as important as a basic advance in emulsion making. It's fairly rare.

What has happened is that at long last we have found some stretch in the chains that lock graininess and light sensitivity in mutual bondage. We can make an emulsion that gives less graininess without yielding sensitivity, or we can have more sensitivity without paying in graininess. The latter seemed the better choice for the first commercial application, which we call *Kodak Royal Pan Film.*

Its graininess is perhaps even a little less than that of the highly satisfactory *Kodak Super Panchro-Press Film, Type B* (fastest Kodak film hitherto offered the press photographer, a connoisseur of emulsion speed), but at the practical gamma of 0.7 it has twice the speed. Exposure Index is 200 for daylight, 160 for tungsten. There is more exposure latitude, more development latitude, more detail in the dark areas, more detail in the light areas, less need for dodging in printing.

If your work, business, or hobby has been crying out for faster sheet film, all you need do now is send someone out to the nearest Kodak dealer for some Kodak Royal Pan Film.

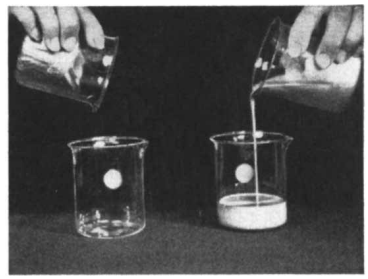
Microprint reader

Now on sale is the *Kodagraph Microprint Reader*, a sleek and unobtrusive instrument intended to create enthusiasm for the microprint idea among those who have had doubts about the comfort of reading microprint day in and day out. This one takes any size of microprint card from 8½″ x 14″ down and thus involves no commitment to any one size. Anyone interested enough to drop a post card to Eastman Kodak Company, Industrial Photographic Division, Rochester 4, N. Y., will be directed to the nearest dealer who can demonstrate why this reader is worth $300.

For gilt

Cellulose acetate butyrate is our pigeon. The fortunes of war and commerce during the past century have often revolved around the results of modifying cellulose chemically. In our own case, it was a happy day when first we looked into the possibilities of introducing butyryl groups among the acetyls in cellulose acetate. That was quite a while ago. Ever since, we have been investigating the dickens out of all possible ratios of acetyl, butyryl, and native hydroxyls on the cellulose structure. The latest facet of our latest triumph concerns bronzing lacquers.

Have you ever found that a can of such stuff, carefully stoppered at the end of work, has turned to a useless jelly overnight? Such is the exasperating way of cellulose nitrate when it serves as a carrier for metal powder.



Now, in the beaker at the right is some lacquer made instead with a new low-viscosity cellulose acetate butyrate we call *Half-Second Butyrate* (from the length of time taken by a standard ball to fall through a standard length of a standard solution of the ester). Both it and its nitrate-based equivalent on the left were prepared 24 hours before the picture was made and treated alike.

This is nothing. We have in one of our laboratories a durable lacquer made with *Half-Second Butyrate* as the powder vehicle over a year ago and given every opportunity to gel under the standard procedure for this sort of test. It hadn't gelled yet at last report.

Though steam radiators are not as common as they used to be, the market for bronzing lacquers remains healthy. Furthermore, the new Half-Second Butyrate *has bright prospects for the high strength and flexibility of its films down to low temperatures, for its low flammability, color retention, and resistance to ultraviolet. It is the only film former with such characteristics that sprays easily. Eastman Chemical Products, Inc., Chemicals Division, Kingsport, Tenn. (Subsidiary of Eastman Kodak Company), will be pleased to send data on formulation for paper lacquers, plastic lacquers, wood lacquers, metal lacquers, heat-sealing adhesives, melt coatings for both cloth and paper.*

Price is 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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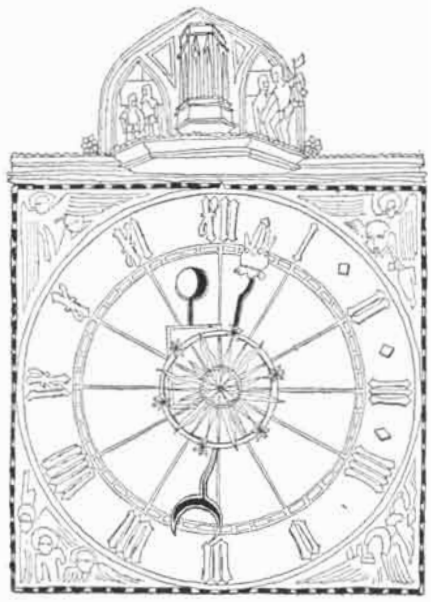

The Oppenheimer Case

The case of J. Robert Oppenheimer will not be a minor incident in history, whatever the verdict of the special Personnel Security Board of the Atomic Energy Commission (it had not rendered its decision when this issue went to press). When Oppenheimer went on trial before the Board, in closed sessions, last month, most scientists in the U. S. were inclined to feel that free science itself was at the bar. They saw at least three causes for concern: that the physicist who was chiefly responsible for the making of the atomic bomb should be rewarded by an accusation of questionable loyalty to his country, that he should be arraigned for youthful opinions and political associations which had been absolved of any sinister meaning by many previous investigations, and, above all, that the chief count on which he was being tried was that he had argued against the development of the hydrogen bomb.

There was a general feeling among scientists that the Oppenheimer case had brought into view a deep-rooted discord between the scientific community and the concept of national security epitomized in Congressional investigating committees and the Federal Bureau of Investigation, which seemed to be mainly responsible for Oppenheimer's suspension.

The University of Chicago sociologist Edward A. Shils said: "It is a frivolous indignity against the scientific profession which has devoted itself without qualifications to the welfare and honor of the U. S. . . . Every honorable man will hesitate, after the suspension of Dr. Oppenheimer, to offer advice to a government which destroys those who turn out to be on the losing side of an argument in an advisory committee."

The physicist Hans Bethe remarked: "It is most disturbing that an opinion expressed in the General Advisory Committee report to the Government can be a charge in a security investigation."

Harold Urey, another of the former leaders in the atomic weapons project, said: "The American people should realize how seriously our science and technology have been damaged."

It had long been widely known that Oppenheimer's early associations with Communists had been investigated before he was cleared for the atomic bomb project in 1942. The new review of "derogatory information" against him was initiated by Lewis L. Strauss when the latter became chairman of the Atomic Energy Commission a year ago. In December President Eisenhower ordered that a "blank wall" be raised between Oppenheimer and classified data; the AEC suspended him from its General Advisory Committee, of which he had been chairman. The special board hearing his appeal consists of Gordon Gray, president of the University of North Carolina and former Secretary of the Army; Thomas Morgan, former president of the Sperry Corporation, and Ward V. Evans, professor of chemistry at Loyola University in Chicago.

When Senator Joseph R. McCarthy charged on a television program that the H-bomb had been delayed 18 months, Oppenheimer himself made public the charges on which he was being tried, together with a long, autobiographical reply. The charges related that an old fiancée, his wife and his brother had been Communists; that he had contributed to Communist causes until 1942; that he had hired Communists or former Communists at Los Alamos; that he had failed to report immediately an approach to him for classified information by an alleged Communist; that a Communist meeting had been held in his home in Berkeley in 1941; that he had opposed the H-bomb program.

Oppenheimer acknowledged that he had associated with Communists in the 1930s and contributed money to causes; but in a remarkable description of a cloistered youth (and a theoretical physicist) he explained his political wild

oats and denied he had ever joined the Communist Party. As for the alleged Communist meeting in his home, he had been able to prove that he was at a ranch hundreds of miles away at the time.

In opposing a "crash" program for the H-bomb in 1950, Oppenheimer was in a company which included David E. Lilienthal, chairman of the AEC; W. Sterling Cole, now chairman of the Joint Congressional Committee on Atomic Energy; and the AEC General Advisory Committee, which included many of the leading scientists and heads of scientists' organizations in the U. S.

Power from the Sun

A little wafer of adulterated silicon which converts sunlight directly into electrical energy was unveiled last month by Bell Telephone Laboratories. This solar battery is an outgrowth of transistor research. It works at an efficiency of 6 per cent, which is comparable to the performance of an ordinary gasoline engine. Bell scientists believe that the figure can be raised to 10 per cent through straightforward engineering improvements. An assembly of wafers covering a square yard could turn out 50 watts of power. The device is not likely to replace large-scale power plants —a 30,000-kilowatt battery would have to cover some 100 acres—but the company expects it to be useful as a small power source for such applications as rural telephone systems.

The battery operates on the same principle that underlies the junction transistor, described by Morgan Sparks in SCIENTIFIC AMERICAN for July, 1952. A "p-n junction" is set up in a silicon crystal. This means that the crystal is divided into two zones, one containing an impurity which produces an excess of movable electrons, the other an impurity which entraps electrons and produces movable "holes" (spaces where electrons should be). Across the junction between two such zones there is always a small voltage. A quantum of light falling on the junction may knock loose an electron from one of the crystal atoms, creating an electron-and-hole pair. Because of the existing voltage difference, the electron is pushed one way and the hole the other. If the zones are connected by an external circuit, a current will flow.

What has made possible the extraction

of usable quantities of power from the arrangement is the discovery of a way to make large area junctions. In the solar battery a strip, about the size of a razor blade, of n-type silicon (containing arsenic) is treated with a gas containing a p-type impurity (boron). Bell engineers have found a way to control precisely the amount of boron taken up and the depth to which it penetrates. They produce a p-type layer less than one 10,000th of an inch thick, with a sharp boundary, over the entire strip. Thus the whole surface becomes a source of current when sunlight falls on it.

Keeping Cool

A new exterior paint that sheds heat has been reported in *Industrial and Engineering Chemistry*, a publication of the American Chemical Society. It is said that a coat applied to a steel roof can reduce the temperature under the roof by as much as 45 degrees on a sunny summer day. Asphalt roof temperatures have been cut 30 degrees or more.

The product, called Plasticool, consists of a flexible resin containing a heat-reflecting mixture of four pigments, one of which is titanium dioxide. The paint will stick to steel, wood, aluminum, asphalt shingle, glass and masonry of all types, according to its manufacturer, Coating Laboratories, Inc.

Solar Mystery Solved

An astrophysical detective search 85 years old was finally ended last month when astronomers at the High Altitude Observatory in Climax, Col., tracked down the last unidentified line in the spectrum of the sun's corona. The bright yellow line proved to come from calcium atoms stripped of all but one of their 15 electrons.

In 1869 astronomers discovered that the corona has a number of emission lines. For 70 years the spectrum was a puzzle, because none of the lines could be identified with any known element. At last in 1940 the Swedish physicist Bengt Edlén proved that the lines come from ordinary elements. The emissions are different from any observed on earth, he explained, because the coronal gases are at very high temperatures and low pressures. Edlén was able to identify the elements responsible for most of the lines, and he suggested tentatively that the yellow line might come from calcium. But it was objected that if calcium was the element, there should be a "companion" line, which could not be found.

Four years ago the Climax observatory

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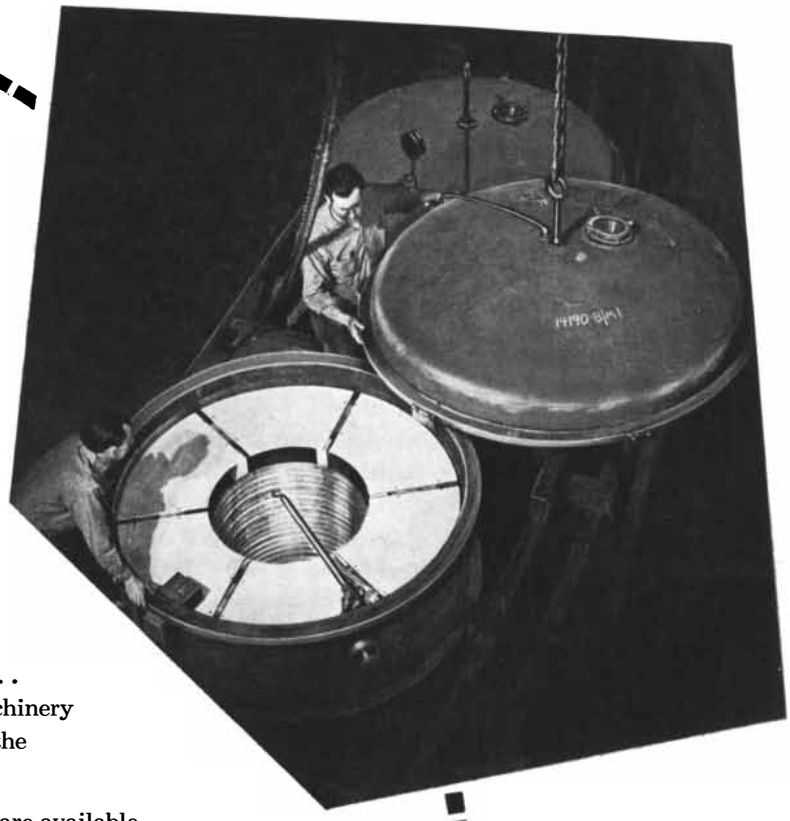

Fifty years of working with vacuum techniques . . . fifty years of building *practical* vacuum equipment . . . plus sixty years of making precision machinery . . . are Stokes' unique background for the production of efficient vacuum furnaces.

Stokes vacuum furnaces of many types are available for melting and casting gas-free metals of extreme purity, high ductility and great strength; for sintering, annealing and degassing. Designs include furnaces for top or bottom pouring, for simple or multiple ingots, for centrifugal casting. 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; two-zone furnaces with movable boat; and others.

A Stokes induction-heated vacuum melting furnace.

Operator regulates booster pump from central control panel. This is one of a battery of 16 Stokes Vacuum Furnaces in a major installation.

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got a particularly good spectrograph of the yellow line (it only appears at times of great solar activity). This year the staff began to study it carefully. Measurements convinced the astronomers that the atomic weight of the yellow emitter must be 40—the weight of calcium. They then made a determined search for the companion line, and soon found out why it had been hidden. It falls almost directly over a strong absorption band originating lower down in the sun's atmosphere, and the two combine to cancel each other.

Walter O. Roberts, director of the Climax observatory, pointed out that while the old mystery is solved, a new one is created. Astrophysicists must now explain the tremendously high coronal temperatures that are necessary to produce a 14-times ionized calcium atom.

Collaborating with Roberts in the discovery were Donald E. Billings and Charlotte Pecker. They have published their findings in the French journal, *Comptes rendus.*

Vaccination for Polio

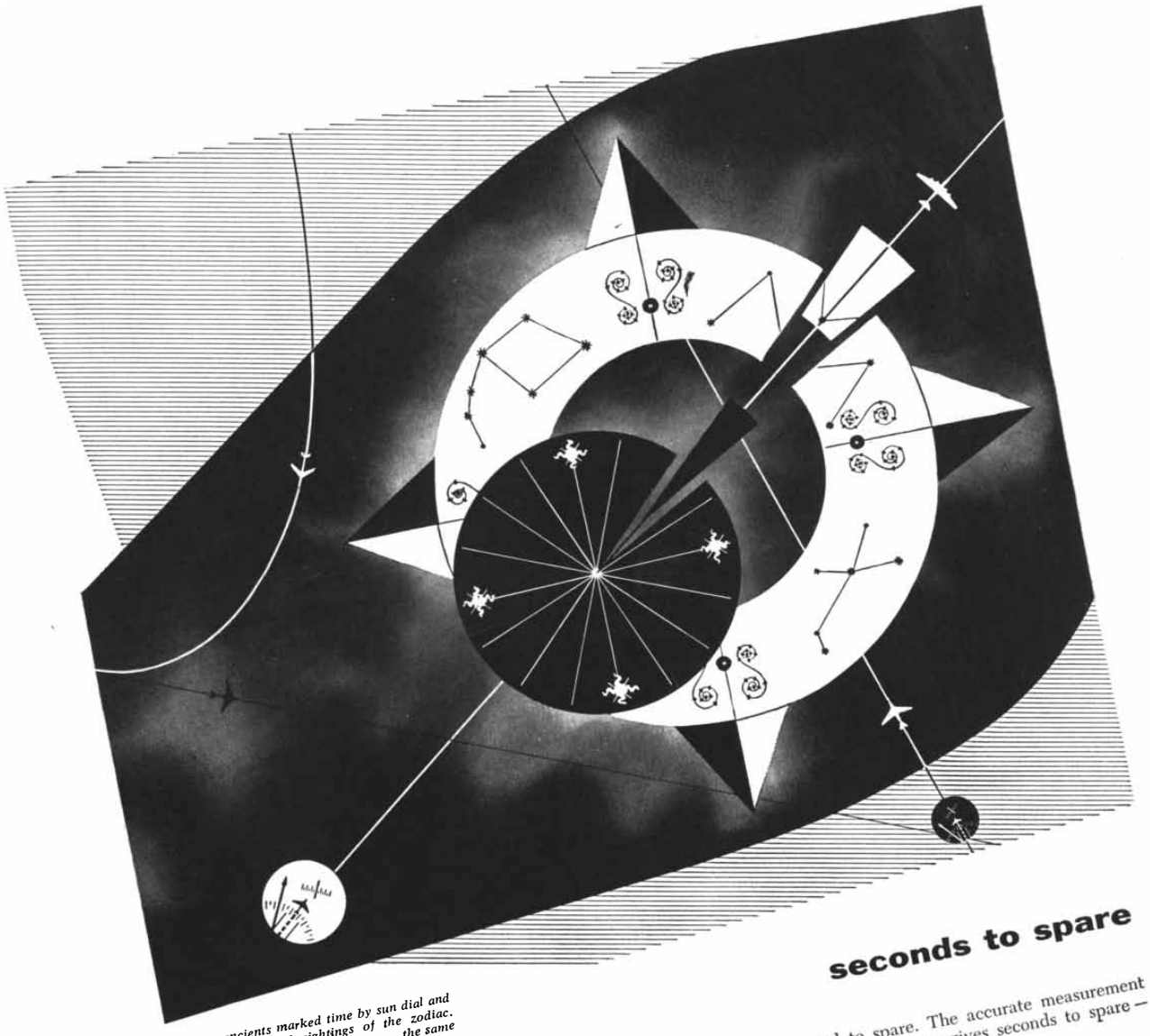
After several weeks of confusion about the safety of the new poliomyelitis vaccine, its mass tests got under way last month. Walter Winchell had told his radio audience that the vaccine "may be a killer" because one batch had been found to contain live virus. The National Foundation for Infantile Paralysis, which is conducting and financing the test, hastened to make clear that each batch of vaccine was subjected to a three-laboratory check which assumed its safety.

The final decision to go ahead with the large-scale tests was made by the Foundation's Vaccine Advisory Committee, headed by Thomas M. Rivers, director of Rockefeller Institute for Medical Research Hospital. The Committee pointed out that Jonas Salk, who developed the vaccine, had given the commercial preparation to more than 4,000 Pittsburgh children, none of whom showed any untoward effects. As to the Winchell scare, "the possibility of infectious activity remaining in any vaccine . . . has been reduced to a point below which it cannot be measured by practicable laboratory procedures."

The Committee established the following conditions for carrying out the program:

No vaccinations are to be started between June 15 and November 1 without the Committee's consent.

No tests shall be undertaken in any area where there has been a case of



The ancients marked time by sun dial and by earth-bound sightings of the zodiac. Today we check the same sun . . . the same constellations, sight Pole Star or Southern Cross, but now we observe them as we fly in space . . . safe in time and place, with Kollsman instruments.

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paralytic polio in the preceding two weeks.

Tests shall be restricted to areas where there is "reasonable assurance" that all children will get the full dose of three shots.

At least 60 per cent of all vaccine must be used in controlled tests, some children receiving the vaccine and others, colored water.

Some 900,000 children in the first, second and third grades will participate in the $7,500,000 program.

Soviet Union in UNESCO

The U.S.S.R. has joined the United Nations Educational, Scientific and Cultural Organization and has applied for membership in another specialized agency of the UN, the International Labor Organization. The Soviet Union had boycotted these agencies. In signing the UNESCO constitution it is pledged "to develop and to increase the means of communication" between the citizens of the U.S.S.R. and those of the other member nations.

Delinquency Begins at Home

Children from "good" homes who habitually set fires, steal, run away or exhibit sexual aberrations are often merely doing what their parents unconsciously tell them to. This is the opinion of two psychiatrists who have spent 10 years treating delinquent children together with their families. Adelaide M. Johnson of the Mayo Clinic and S. A. Szurek of the University of California Medical School believe that a parent with antisocial impulses which are suppressed but "poorly integrated" derives vicarious pleasure from seeing his child carry out those impulses. Speaking of delinquent behavior that does not stem from slum conditions or membership in a juvenile gang, the psychiatrists say that in every case where they have been able to examine both the child and his parents, "the child's defect in conscience was traceable to a like defect in the parents' own poor resolution of unconscious impulses to similar antisocial behavior."

In an article in *The Journal of the American Medical Association*, the physicians give a few examples. A woman whose brother used to set fires and of whom she was very jealous as a child finds her own five-year-old child playing with matches. She tells the child to stop playing with matches, but adds that if he "insists on fires" he may burn some papers in the sink. This illustrates "a technique, concocted of vacillating pro-

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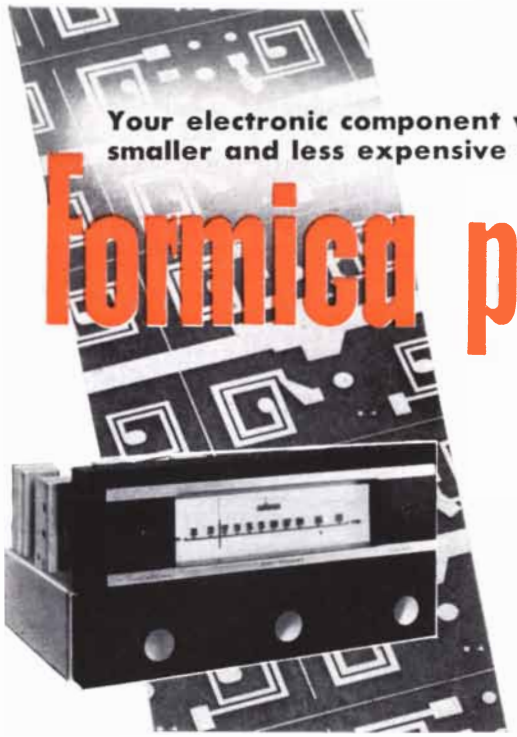
Non-Linear Systems, Inc., Del Mar, Calif., manufacturer of the Digital Voltmeter, found Formica nylon base printed circuits offer these important advantages: (1) Enables unskilled labor to assemble this complicated electronic instrument faster, easier, cheaper; with possibility of error almost negligible. (2) Reduces undesirable noise pick-up without shielding critical leads. (3) Assures exact wiring duplication. (4) Reduces cost of maintenance. (5) Establishes uniformity of performance in each Voltmeter produced.



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hibition and permission, for inadvertently encouraging the behavior."

Children can sense the underlying gratification which parents derive from their exploits even if the parents affect complete disapproval. A truck driver has been forced to give up his job driving trucks across the country, which he likes, for one that confines him to the city. His four-year-old son tries to run away from home. When the father brings the child in for treatment, it is striking to see how eagerly he presses the boy to tell of his flight. A mother who has strong impulses toward sexual promiscuity begins to be obsessed with fears about her daughter when the child is nine. When the girl starts dating a few years later, the "detailed suspicious questionings and the dire warnings" to which the daughter has been subjected lead to the very type of behavior which the mother feared and unconsciously wanted for herself.

Drs. Johnson and Szurek say that this parent-child relationship is difficult to treat. It can usually be discovered only when two psychiatrists work as a team, one treating the child, the other the guilty mother or father. The severe neurotic symptoms which result when a parent is brought to realize what he has been doing may be hard to cure. But it is better to face the neuroses than to allow the antisocial behavior in children, "with its threat of perpetuation through generations."

Non-Mechanical Brains Revolt

The British aircraft carrier H.M.S. *Eagle* recently experienced an epidemic of strange happenings. Electronically controlled guns refused to move; automatic sprinklers suddenly went off and sprayed the planes on the ship without apparent cause; busy machines mysteriously fell silent. The goings-on provided considerable copy for the British press before the cause was discovered. It turned out that the ship's crew, pushed to the wall, were simply hazing the mechanical brains by way of protest.

The men have been crowded nearly off the ship by electronic gadgets. Radar sets and automatic control devices take up so much room that the crew must sling its hammocks in odd corners and queue up for an hour to get a meal. Water is rationed because machines have replaced some of the storage tanks. So the sailors began to extract a vacuum tube here, drop a quiet monkey wrench there. The press, as over-hasty in taking reassurance as it had been in taking alarm, was naively relieved to learn that the trouble was not foreign sabotage but just a revolt of the crew.

To **1954** *Engineers...*

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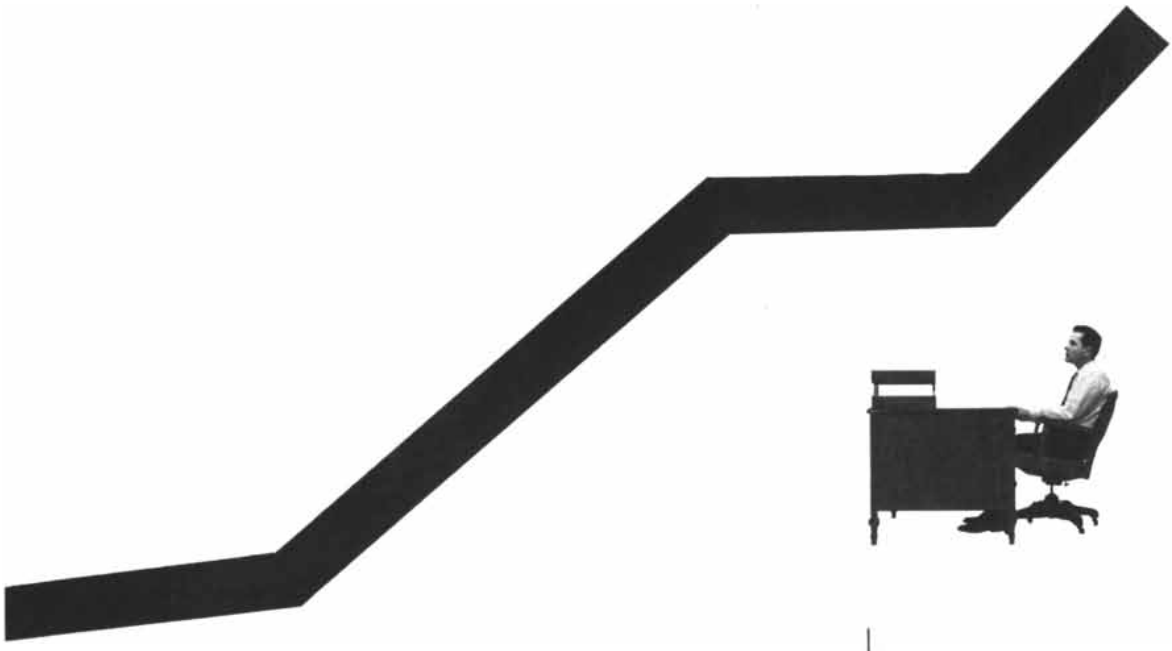

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The Electrical Activity of the Brain

By recording the pulsation of tiny currents from various parts of the head the electroencephalographer diagnoses brain disorders and studies the basic mechanism of mind

by W. Grey Walter

Twenty-five years ago Hans Berger, a German psychiatrist working in Jena, began to publish some strange little pictures consisting of nothing but wavy lines. They should have caused great excitement among his colleagues, because he claimed that they showed the electrical activity of a human brain. But in fact no one took them seriously. For several years no one even bothered to repeat his experiments.

Berger was naturally hurt and disappointed that his epoch-making discovery was ignored or ridiculed. But there were three understandable reasons why any well-trained scientist should have dismissed Berger's claims. First, it was not considered really respectable to study the activity of the brain with measuring tools. Classical scientific methods depend on measuring one thing at a time as exactly as possible, and it was plainly impossible to isolate the individual functions of the complex human brain. Second, the "brain waves" Berger published were altogether dull—merely a tiny electrical oscillation at about 10 waves per second. It was inconceivable that these simple, regular lines could disclose anything significant about so mysterious an organ as the human brain. Third, Berger had rather unwisely admitted that he was looking for what he claimed to have found; psychiatrists, rightly or wrongly, have a reputation for being able to find proof of their wildest ideas when it suits their beliefs.

This little episode in the history of brain research should be a lesson to everyone with a brain to study, for it shows that curiosity and imagination are too easily stifled by the usual scientific training, emphasizing self-criticism and technical skill. Berger was in fact a modest and careful observer; his misfortune was that his technique did not equal his enthusiasm. In the quarter-century since then the study of his little wavy lines has grown into a new department of science called electroencephalography. Today several hundred laboratories in the U. S. and a similar number in Europe are recording and interpreting charts of the electrical discharges of human brains. Their total annual output of charts would girdle the earth. Hospitals all over the world have accumulated thousands upon thousands of brainprints of their patients, for these recordings have proved to be a great help in the diagnosis and treatment of brain diseases.

Brain diseases leave prints as distinctive as a criminal's fingerprints, and the brainprints have been useful in medical practice for precisely the same purpose—to identify the culprit. Just as a fingerprint serves this purpose although its details reveal nothing about the criminal's character, so a brainprint may be put to use for identifying a brain disorder even though we do not understand what it may have to tell about what is going on in the brain. The detective work involved in tracking down the clues to brain diseases is so exciting that at first scientists were content to exploit this aspect of electroencephalography and to postpone more fundamental investigations. During the last few years, however, interest has been swinging round to use of the tool to study the working of the living brain itself.

By a fortunate coincidence—or perhaps it is not a coincidence—the designers of the new electronic computers have, at the same time, become more and more impressed with the similarities between their machines and the mechanisms of the brain. Physiologists have had the satisfaction of seeing engineers develop, with great labor and expense, systems which evolved naturally in living creatures millions of years ago. This convergence of interest—the cross-fertilization between communication engineering and biology—has been given the name cybernetics, originally used by the French physicist André Marie Ampère over a hundred years ago. Norbert Wiener, professor of mathematics at the Massachusetts Institute of Technology, focused interest on the subject with his book in 1949, and it has since been pursued at several conferences convened by the Josiah Macy Jr. Foundation. Through these discussions runs a thread of longing and conjecture—if only we could unravel by our physical methods the mystery of how the brain functions!

The Instrument

The machines that record the electrical rhythms in the brain have become elaborate and expensive. They contain dozens or even hundreds of radio tubes. A really elaborate research apparatus may have several hundred controls, set and adjusted by a team of highly skilled operators before and during each experiment. The cost of the equipment is usually defrayed by the fees earned in medical applications; the gigantic scale of this

work could never have been achieved with the funds available for academic research. The astonishing thing is that with all this time and material we still do not understand even one part in a thousand of the frantic scribblings of our fine machines.

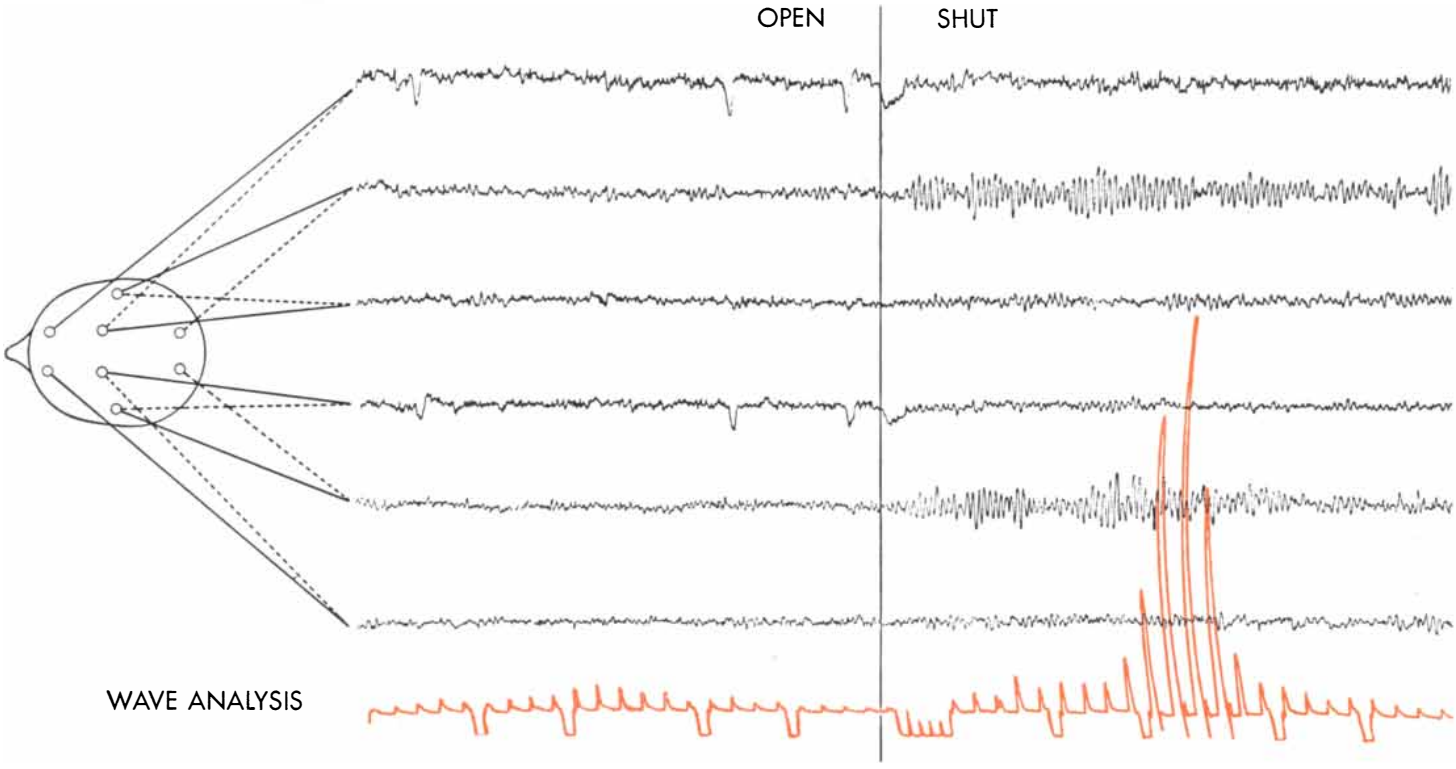
The standard electroencephalographic chart shows a set of eight or more wavy lines, each line being a graph of the electric signals from one region of the head. We may suppose—and it is only a supposition—that these signals are coded messages from the brain, and our task may be defined as a search for clues that will help us to break the cipher and read the messages. The usefulness of the brainprints in diagnosing disease lies in the fact that we have established that serious emergencies in the brain usually yield certain simple code messages in our machines.

The signals are usually classified by the frequency of the electrical pulsations in them. Berger's original oscillations, which he named *alpha* rhythms, are in the frequency band between 8 and 13 cycles per second—that is, about as fast as you can move a finger. Their size, or amplitude, is around 30 millionths of a volt. Neither the frequency nor the amplitude is constant. Each individual has his own characteristic pattern of shifts in frequency and size; thus his brainprint is as distinctive as his signature. The alpha rhythms also can be identified by the part of the brain they come from; they are nearly always largest at the back of the head, where the nerve signals from the eyes reach the brain. They are usually larger and more regular when a person has his eyes shut and is not thinking. From this the inference has been drawn that activity of the visual imagination may suppress the alpha rhythms. One person in five shows no alpha rhythm at all—only small, complex, irregular pulsations from all parts of the brain, with no fixed frequency. In one in five also the alpha rhythms go on even when the eyes are open. Upon the basis of such personal differences we have established a tentative classification of brain types in human beings. This system indicates differences in ways of thinking, rather than the relative success of people's thinking, as "intelligence tests" do.

Let it be said at once that nobody has yet been able to determine precisely the meaning of the alpha and other electrical rhythms of the brain. Nonetheless they are much too prominent, too individual, too persistent—and already too clearly related to mental activities—to be dismissed as "disappointingly constant," as they were when the brain physiologist E. D. Adrian demonstrated them at Cambridge University in 1934.

Some time ago I was struck by a peculiar coincidence. I had reflected a thousand times that the brain rhythms are a unique phenomenon: Nowhere else in nature are such intricate patterns to be found, such variety, such interweaving of differential frequencies in their ever-changing combinations and permutations. On the thousand and first

ELECTROENCEPHALOGRAM is made at the Burden Neurological Institute in Bristol, England. The electrodes are attached to the scalp of the subject, who is seated with an investigator. Where an electroencephalogram is normally recorded on a paper tape such as that in the foreground, here it is also displayed on a device called the Toposcope, the face of which is visible at the upper left.



ALPHA RHYTHMS are recorded. Each curve in black represents the fluctuations of current from electrodes attached to the head as indicated by the drawing at the left. The red curve is drawn by a wave analyzer which periodically dissects the frequencies of which the fifth curve from the top is composed. The tallest red spike on this page, for example, records the average amplitude of a frequency

reflection I followed up this thought with the question: What is the unique function of the brain? The brain's unique function is to learn. The conclusion from this seemed inescapable: probably there is some kind of coupling between learning and the brain's unique physical activity—its electrical rhythms.

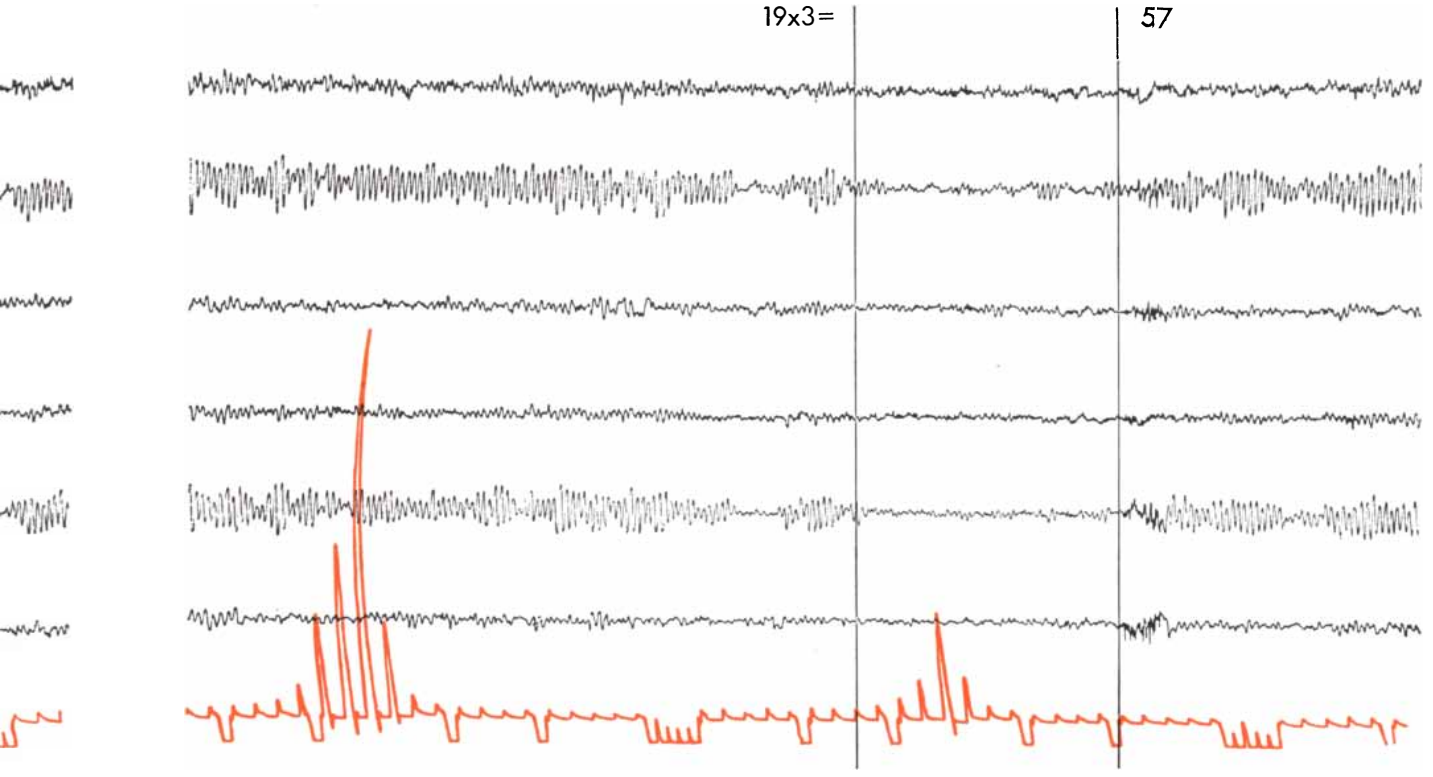
Since then we have gone some way toward verifying the learning theory, as will be told later in this article. But the immediate problem that presents itself to the thoughtful reader will be: What is the physiological function of the electrical rhythms? Apart from such end results as learning, what are the rhythms for, what do they do, what is their special role in brain mechanisms?

The Brain's Communications

Let us concentrate on the alpha rhythms, definitely known to be associated with vision. One of the great physiological puzzles about vision is this: When an image is received by the brain, how is it passed on to the cognition areas? We know that a scene registered on the retina in the eye is projected on a section of the brain cortex by the optic nerve—a compact bundle of a million or so nerve fibers. From the visual projective cortex, information about the things seen is somehow transferred to billions of other cells in the brain. Can we imagine that the million points of projection are connected with all those billions of cells? It is quite inconceivable that anything like the necessary number of physical links could be housed in the head. We are therefore led to the suggestion, derived from the examples of radar and television, that communication between the projection and the cognition areas must be by a scanning mechanism.

This suggestion gains force when we consider what may have been the evolutionary origin of brain rhythms. Such a rhythm means that a group of millions of brain cells are firing together at regular intervals. The most primitive living example of cellular collaboration of this kind is the jellyfish. We may suppose that an early form of jellyfish depended for its existence upon the food signals received by its nerve net, which produced a convulsion (comparable to an epileptic seizure) that propelled the animal toward the exciting food. Such an action implies a combined discharge of many motor cells. The nerve net presumably consisted of specialized food-and-motor cells and steering cells. A cell receiving the food stimulus would pass it to the steering cells and these would transmit it to the other motor cells almost—but not quite—simultaneously. In other words, besides the time lag always required for recharging the cells, there would be a time lag in the communication of the signal to all the cells. There is already here something suggestive of scanning; the whole of the forward nerve net would be open to suggestion and the impulse would be propagated by whichever cell first received the incentive.

Further evolutionary specialization might produce a system in which the signal or incentive was passed from the perceptive cells to the steering cells and from there to the motor cells, the steering cells thus assuming a primitive brain function. This is where one would have to look for a rhythmic discharge like that of the alpha rhythms. It has been suggested that the alpha rhythms may be a necessary periodical wiping out of the impressions received on the visual projection cortex. Such a process may seem plausible in a primitive perceptive-steering-motor system, but it would not account for the phenomena of the human brain. Moreover, for a primitive system such as the one described it would not be necessary. The discharge of the steering cells as they communicated their impulse to the motor cells would itself wipe out the previous impression and allow them to present a clear field for the next impulse. But again to carry the matter a step further in brain evolution, the time



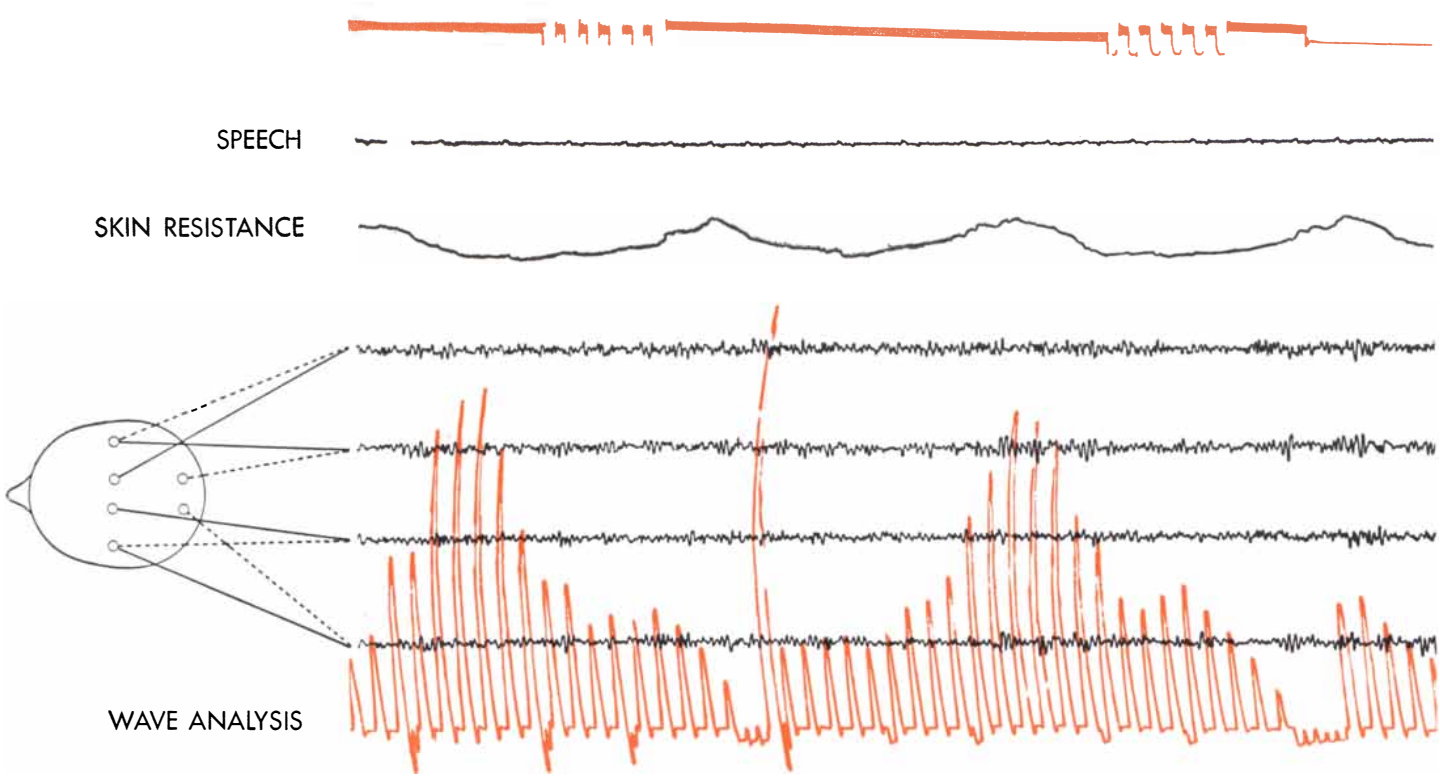
of 10 cycles per second; the spikes to the left of it represent the amplitude of nine cycles, eight cycles, seven cycles and so on. To the left of the vertical black line on the opposite page the subject's eyes were open and the alpha waves are small; to the right, his eyes were closed and the waves are larger. When he was given a problem in arithmetic (*above*), waves were damped until he gave answer.

lag in transmission of the signals would establish an inherent rhythmic sympathy among all the steering cells, geared to the period of the passing of signals from the perception cells. Putting it very crudely, this is in effect what seems to be taking place in the human brain: the alpha waves sweep to and fro scanning the visual cortex in harmony with the period during which a scene is retained by the transmitting retina.

As already mentioned, the diversity of alpha rhythms is their most intriguing property. What, however, are we to say about the many people who display little or no alpha rhythm? According to the scanning hypothesis, their scanner must be working at very low amplitude, yet these are the people in whom visual imagery is most vivid and persistent. At first this seemed a crude paradox, but we were blinded by the vision of familiar machines. In a TV set, scanning of the field goes on continually whatever the picture may be; in certain radar sets designed to control artillery and in many target-seeking projectiles, a scanner is set to search for targets, but once an echo has been received the scanner stops and swings the gun or missile into a position of best attack. This simple system was incorporated into the toy robot, *Machina speculatrix*, which we made years ago to see how "scanning" would affect behavior [see "An Imitation of Life," by W. Grey Walter; SCIENTIFIC AMERICAN, May, 1950]. In systems such as these, the more active and excited the system is, the less regular and rhythmic the scanning cycle becomes. So perhaps within our heads we carry a bundle of target-seeking tissue—in origin primeval, but in function as penetrating and as precise as any imagined, even in the realms of science fiction. Here we can discern at work the organ of selection and imagination, first stages on the road to learning, understanding and foreseeing the shifting patterns of the outside world—and all contained in a cupful of tepid, pinkish-gray, electric jelly.

The Brainprint

To complete the panorama of the strange dark world within our heads, let us look at the brainprint itself. Learning to understand brainprints is rather like learning a foreign language from a number of acquaintances with different accents and dialects. Now there are two things which often astonish a visitor to a foreign land: (1) the ease with which young children speak the tongue, and (2) the similarity of baby talk in all countries. We are called mammals because "ma" is one of the first syllables human babies everywhere fix upon, and they seem to apply it to the maternal organ which first regularly attracts their attention. There are similar characters in brainprints. At birth the brainprints of infants are generalized, but at an early age, around three or four, the child's brainprint acquires the individualistic features of an adult's. In a newborn babe there are slow, rhythmic swings of electric change in all areas of the brain, the different parts acting in the same way electrically but without much coordination. During sleep the brainprints of babies are very like those of sleeping adults: mainly large, slow, regular oscillations, called *delta* rhythms. Some time during the first few months of life an important mechanism appears—a transient outburst of fast and slow rhythms when the sleeping baby is half awakened by a noise or movement. Most parents are only too familiar with the transition from an infant who will sleep through almost any racket to one which stirs at the creak of a floor board. The same electrical response to stimuli when asleep is seen in adults. In most cases it seems to be connected with the brain mechanism that prevents a sleeper from being awakened too easily by trivial noises; it has been called the "K" complex. In later life these safety mechanisms are usually very sharply tuned, as it were, so that a mother may sleep through a thunder-



VERSATILITY of an individual brain is suggested by the variability of its rhythms over a relatively extended period. Constant rhythms are associated with low versatility; variable rhythms, with high versatility. In addition to the four electroencephalographic curves on this record are curves for speech and the electrical resistance of the skin. Here the tallest spikes on the red curve of the wave analyzer merely mark intervals of 40 seconds. The groups of shorter red spikes dissect the frequencies of the black curve

storm but wake when her baby whimpers.

During the first few years of life the slow rhythms get steadily smaller as the nerve fibers in the brain complete their growth. At about the end of the first year another sort of rhythm appears. It has a frequency of five or six per second and is largest at the sides of the head. It seems to be connected in some way with what we call emotion, particularly with feelings of annoyance and frustration. In children of about three years old it can be evoked very easily by teasing—by offering a piece of candy and then snatching it away again. Another similar rhythm can easily be evoked by simple physical pleasure. These rhythms have been called *theta* rhythms, because they seem to be connected in some way with the functioning of the thalamus, the midbrain where signals from the body are relayed to the brain roof. The theta rhythms usually appear at that phase of development when children start to acquire self-control. The age at which this happens varies, and so do the size and character of the theta rhythms.

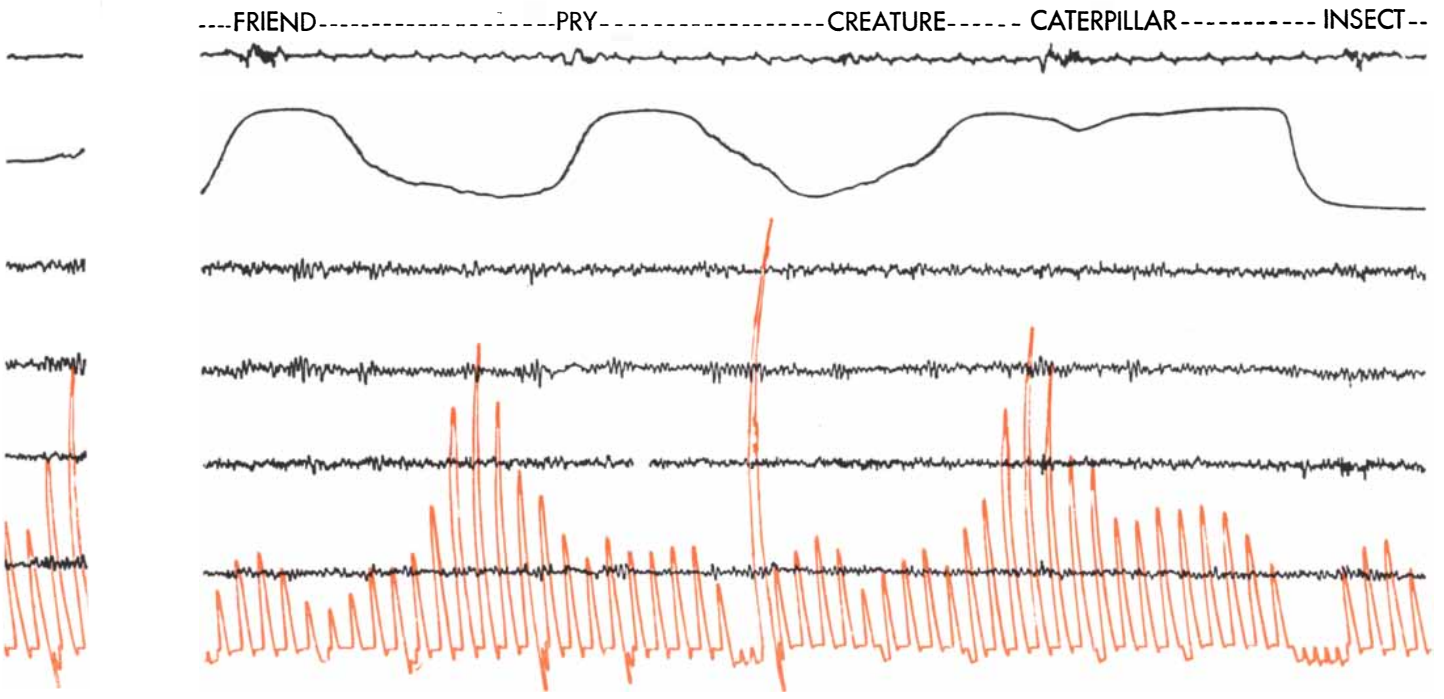
The first sign of alpha rhythms is seen clearly during the second or third year, but the faster components rarely appear until the age of seven or eight. The theta rhythms and alpha rhythms are present together in varying proportions until the age of 13 or 14. Consequently the interpretation of children's brainprints is particularly difficult, demanding appreciation of psychological and social factors influencing the individual child. For instance, adults usually submit to electroencephalography calmly, but for children the mere fact of being in a hospital, of not being allowed to sit on mother's knee, of having to keep still and so forth, has a startling effect on the brain activity. It is often possible to tell a good deal about a child's fears and interests from the way in which the brain rhythms change during a recording or from one examination to another. His brainprint may even vary according to whether the operator is wearing a white or a green coat.

An adult whose brain becomes diseased or injured, or who has a childish personality, may revert to the slow delta and theta rhythms of infancy and childhood. In certain conditions of strain unusually fast rhythms appear. In certain types of epilepsy there is a characteristic combination of enormous slow waves and fast spikes. Naturally the exact location of these abnormal features is a very important part of electroencephalography, for it can pinpoint a disturbance for an operation by a brain surgeon.

This catalogue of the signals received from the living brain may give a misleading impression of simplicity. Only in very severe or advanced stages of a brain disease are the brainprints so clear that their features can be designated with complete confidence. Far more often all these slow and fast components appear together intermittently or continuously in various parts of the brain, all of them varying with the state of the person being studied. The record is usually more like the score of a symphony or the transcript of conversations at a cocktail party than a simple code message. Whenever it takes on the character of a solo or a monologue, one knows that something has gone seriously wrong, either with the brain or with the recording machine.

Disentangling the Signals

Using again the analogy with cipher breaking, the difficulty with electroencephalography is not to pick up a message but that inevitably a great many different messages are received at the same time. This situation has demanded several refinements of technique. The human eye is ill-adapted to sorting out the components of a complex curve. Sometimes different rhythms combine in such a way as to give a completely false



at the bottom for the previous 40 seconds. While the record at the left was being made, the female subject rested; while the record at the right was being made, she spoke a series of words (*top of record*) which came into her mind spontaneously. The lack of variation in the wave analysis suggests low versatility. As she spoke the words, there were changes in her skin resistance indicating an emotional disturbance. This disturbance was reduced by the transition from thoughts about friendship to word "caterpillar."

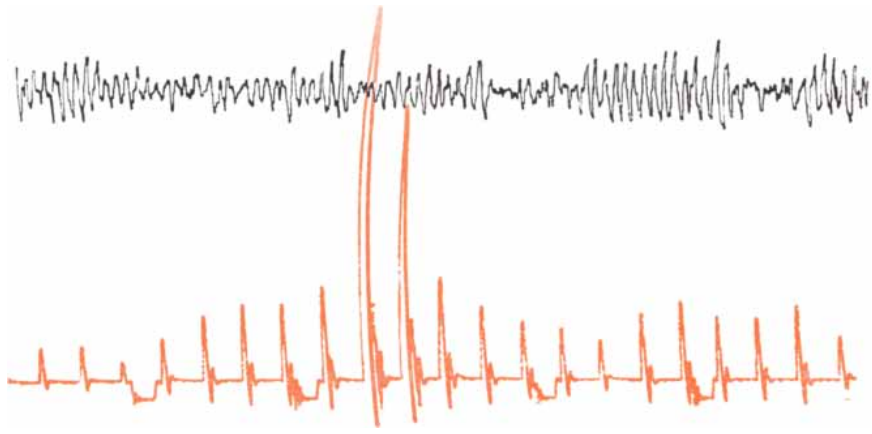
impression. For example, during an examination in which a person becomes annoyed by something, the curve may change in a way which seems to indicate that the frequency of his alpha rhythm has dropped by one or two cycles per second. Actually the true change may be the breaking out of an entirely separate theta rhythm which is imposed on the alpha.

To unravel the situation many laboratories now employ special wave analyzers. These instruments deal with the complex electrical oscillations from the brain in rather the same way as a prism separates the colors in a beam of light. The components of the complex wave are isolated by electronic circuits tuned to the several frequencies. A moving pen automatically records the amount of activity at each frequency during a fixed interval, usually 10 seconds. The result is a set of curves giving the frequency spectrum of the brainprint. This process is repeated over and over, and other electronic circuits write out the statistical average of the spectrum readings every minute or so, so that the experimenter can measure not only the composition of the brain signals from time to time but also their variability over a longer period. From this can be assessed the versatility of the brain under investigation—an important measure of its repertoire of adaptive stratagems.

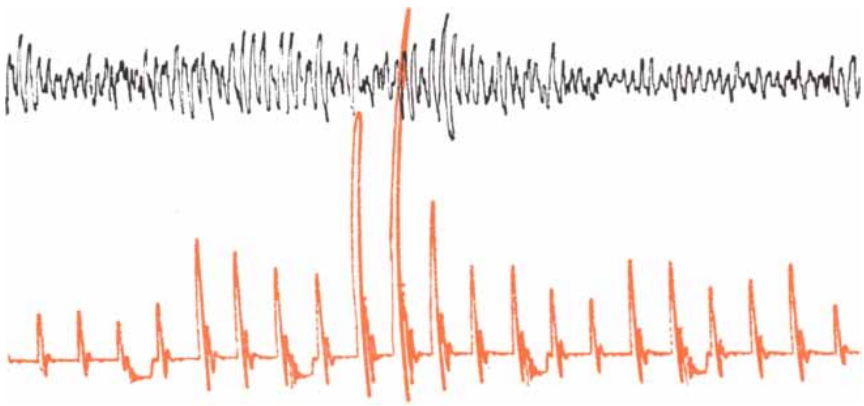
Frequency analysis by this means has proved a valuable tool, but like all tools it has its limitations. It cannot easily be applied to more than one part of the brain at once. Few laboratories can afford more than two analyzers, for they cost upward of $5,000 apiece. Furthermore, frequency analysis can be quite misleading unless it is used imaginatively; it can only suggest possible solutions to a problem, and the experimenter must then make further studies to decide which of the possible solutions is correct. Since the state of the brain is always changing, the fresh tactics suggested by frequency analysis may come too late to be of immediate value. Again, using the cipher comparison, frequency analysis will not give information about how the rapidly changing signals from different parts of the brain are related to one another, or which of the suggested meanings is the most likely one.

A State of Mind

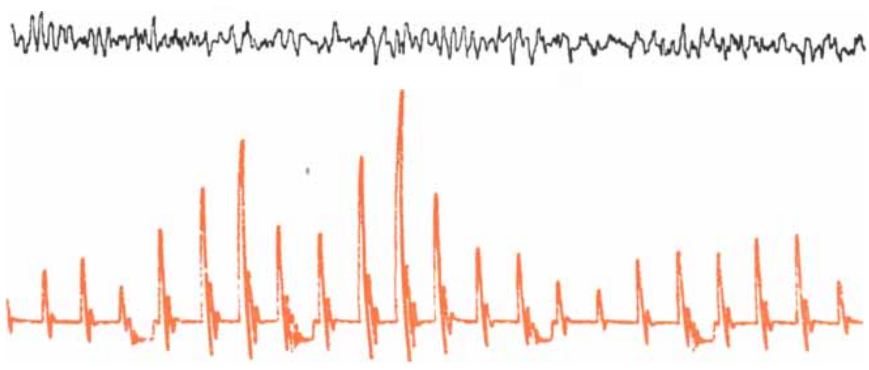
Yet the sort of insight that frequency analysis is capable of providing is vividly illustrated by a recent laboratory experience. The investigator had just taken delivery of a new analyzer and had spent a Saturday morning tuning and calibrating his new treasure. By afternoon he was ready to try it, but the only test subject left in the laboratory was a technical assistant who had, by ordinary standards, rather a dull record. (Electroencephalographers mean no offense when they call a record "dull"—in fact, the best companions often give the dullest records. The reference is only to the lack of larger regular oscillations.) On this Saturday afternoon an international football match happened to be going on, and the subject listened to the radio while the test proceeded. After a few minutes the experimenter, who was not listening to the radio but was busily adjusting the settings of his new instrument and checking the consistency of its analysis, began to realize that he was unconsciously following the progress of the football game as it affected his subject. At first, when the home side was in the lead and the play was relatively uninteresting, the subject's alpha rhythm droned on at nine cycles per second, and there was only a trace of theta activity. Then the game livened up; the analyzer promptly showed an alpha rise to 10 cycles per second. When the visiting team scored a goal, the theta rhythms suddenly increased to the size of the alpha rhythms. This complex spectrum of theta and rapid alpha activity



HOME TEAM LED at this point on the record of a man listening to a football match on the radio. The tallest spike of the frequency analysis (*red*) represents nine cycles per second.



HOME TEAM SCORED at this point. The tallest spike of the frequency analysis represents 10 cycles per second, indicating that the amplitude of that frequency has increased.



VISITORS TIED the home team at this point. The tallest spike of the analysis represents 10 cycles, but there is now a six-cycle spike associated with the annoyance of the subject.

persisted with only minor fluctuations until the game ended with the defeat of the home team. One may say that, knowing the score, one could tell the nationality of the subject from his brainprint, or knowing the subject, one could infer the state of the game. Testing a roomful of people, the instrument could show which of them were interested in football and whether an individual's interest was mainly in the niceties of play or in which side won.

Prolonged and detailed analysis of records from normal subjects has shown that the spectrum of alpha rhythms is far more complex than was at first supposed. When a person is performing a task—*e.g.*, trying to recognize an object by its feel—the various components in the alpha band wax and wane in a manner absolutely characteristic of that person. One component may be linked with the attempt to visualize what has been felt, another with a search for verbal expression, another with the recall of visual impressions, another with the effort to imagine a color, and so forth. For each person there are typical combinations and permutations of rhythmic change, associated with the way that person prefers to solve problems and handle the model of the world his head contains.

Decoding the Messages

To watch the unfolding brainprints of a friend is an absorbing experience, particularly if you have some idea of his state of mind and interests of the moment. You have the impression, however, of listening to a muttered soliloquy through a keyhole. You itch to ask a leading question, but only rarely can you frame a question simple enough to evoke an intelligible change in the brainprint. In 1945 there was introduced a method of stimulation, simpler than ordinary language, which has vastly extended the scope of electroencephalography. It is based on a principle well known to cryptographers. If you are trying to break a code, a useful trick is to force the enemy to send a message of your own selection: *e.g.*, "100 bombers approaching." When you pick up this known message in his code, you have the key in your hand. Radar, which obtains information from a reflected radio pulse of predetermined frequency, is another aspect of much the same principle. The idea was applied to the study of the brain by stimulating the eyes with very short flashes of light at controlled intervals.

The way this method developed is an interesting example of interplay between

clinical needs and scientific conjecture. When frequency analysis was first applied to brainprints from epileptics, it was discovered that in many the rhythms had a tendency to appear in distinct bands with an almost arithmetical relationship to one another. For example, there might be activity at the frequencies of 3, 6, 9 and 24 cycles per second. During an epileptic fit these highly distinctive patterns became pronounced. This suggested that a seizure might be induced by electrical stimulation which accentuated the "harmonic" relation between these rhythms in different parts of the brain, or which synchronized the rhythms and supplied missing links in the harmonic series—12, 15, 18 or 21 in the example given. This sounds cruel, but the diagnosis of epilepsy is never sure until an attack has been seen by an experienced observer, and all kinds of disagreeable methods have been suggested for inducing an attack in unfortunate people who may be epileptic. The flicker method of synchronizing the inherent brain rhythms seemed to be relatively gentle and promised to be scientifically illuminating. Almost the first time the method was tried on a known epileptic, a dramatic success was achieved; the moment a certain combination of light flashes was established, the patient underwent one of his characteristic attacks. The success of this clinical stratagem naturally encouraged more detailed study of the way normal brains responded to flickering lights, and it was soon found that in most people stimulation of this sort evoked in the brain extraordinarily complicated and widespread responses.

Among other discoveries, it was found possible to make the brain stimulate itself by positive feedback. The electric impulses from the brain were connected through the recording machine to the electronic gadget that produced the flashes of light. In this way a brain response to a flash triggered a new flash and so on. This method of self-excitement is particularly effective for revealing a hidden tendency to epileptic seizures. It resembles very closely the way an engineer may test the stability of a transmission system: he applies positive feedback to disturb the system and observes how effectively the system's inherent negative feedback operates to damp the disturbance and restore equilibrium. A normal brain contains an automatic gain control which prevents overexcitement even during positive-feedback flicker experiments.

The importance of these discoveries is that they demonstrate the dynamic and personal response of the brain to a stimulus. When it receives a light signal, it sends a coded message to nearly every part of the brain. Usually messages arriving in brain regions far from the visual receiving department evoke no action; they are "to whom it may concern, for information only." But the administrative rules, so to say, are not watertight; the signaling procedure has certain weaknesses. In many epileptics and even in one normal person in 20, the relayed message is acted upon immediately by the executive part of the brain and something like an epileptic fit results. It is as though all the officials in a government office were to reply in exhaustive detail to instructions intended only for a single department. The reason flicker stimuli are so potent seems to be that they overwhelm the brain's channels of communication with their barrage of rapid, repetitive impulses. You cannot drive a nail into a piece of wood with your finger however hard you push, but the same amount of energy applied in repeated hammer blows will do the trick.

The Meaning of Flickers

An encouraging feature of the flicker stimulation method is that anyone looking at the flickering light sees more than just flicker. There is always a sensation of movement, pattern and color, though the stimulus is stationary, featureless and without distinctive hue. Margiad Evans, a novelist who underwent this experience, described her sensations as follows:

"Lights like comets dangled before me, slow at first and then gaining a furious speed and change, whirling color into color, angle into angle. They were all pure, ultra-unearthly colors, mental colors, not deep visual ones. There was no glow in them, but only activity and revolution."

Red flickers are more effective than those of any other color. Some people develop exaggerated electrical responses and sensations only with red flicker. Conversely, it has been found that some epileptics have fewer spontaneous fits when they wear spectacles that screen out the red wavelengths of light.

The cause of these visual illusions during flicker has intrigued us considerably. The intricate moving patterns may be subjective evidence for the scanning process outlined above; we have found that brief, intermittent stationary signals applied to a space-time converter or scanner will always produce an illusion of pattern or movement, just as such signals applied to a moving system can provide an illusion that the system is stationary—the stroboscopic effect. A person contemplating the illusions of "activity and revolution" is, in effect, examining the sweep of his own brain, raking and sifting the clutter of signals for anything which may have meaning or value.

From the experimental standpoint the outstanding virtue of the flicker method is that the stimulus is "tagged" with the frequency at which the light is flashing, so that frequency analysis can be used to particular advantage. Brainprints contain a great deal of confusing information—activity unconnected with the particular experiment. These interfering signals cannot be eliminated, because they are an essential part of brain functions—the sign of continuous active adaptation in the organ of adaptation. In searching for the response to an experimental stimulus against this background we are rather in the position of someone who has an appointment to meet a strange lady at a busy terminus: how to pick her out of the throng of passersby? The usual solution is to arrange to wear a flower of a certain color and wait at a certain place at a certain time. The combination of flicker and frequency analysis has the same effect. The stimulus has a known frequency and the amount of spontaneous activity at that frequency in the various parts of the brain can easily be measured beforehand. Any increase in the activity at that frequency during the stimulation period can be seen quite clearly in the analysis, even when it is completely hidden in the busy crowd of other rhythms and discharges. A regular response only one millionth of a volt in size can be measured even when the interfering signals are 20 times as big. Viewed in this way, the strange, remote responses to flicker are rather as though, having arranged to recognize a blind date by her red carnation, one came upon all her uncles and aunts in every corner of the rendezvous, wearing flowers of similar shades and with mysterious assignations.

Meeting under the clock has romantic associations, but the comparison with frequency analysis is not quite accurate; though we can recognize very small rhythmic signals by their frequency, the time and place of their occurrence are indeterminate. The ordinary written record could supply this information, but to interpret the multiple responses in detail is like listening to half a dozen witnesses all giving their testimony at once and chattering to one another as well. We wanted something that would give

evidence in a curt, formal way, would be content to answer "yes" or "no" to leading questions, and would indicate when there was general agreement about the responses in different parts of the brain. We dreamed of developing a combination of expert witness, learned counsel and impartial jury.

The Enchanted Loom

In 1947 we began to work out an entirely new method of displaying brain signals which we hoped would enable us to eliminate the interference from irrelevant signals—to cloak with invisibility the crowd of strangers milling around our dear unknown. The machine that has "just growed" in our laboratory is called the Toposcope—Topsy for short—because it was originally intended to show the topography (space pattern) of the brain activity. Like the Taj Mahal, which it faintly resembles, the conception has grown in scope by marriage to four other instruments (each with its technical and pet name) so that it is now much more than merely an indicator of the topography.

In principle Topsy is rather like 22 small television or radar sets. Twenty-two little cathode-ray tubes, each connected by an electrode to a different region of the subject's head, translate into visual form, as pictures of changing brightness, the activity of the respective parts of the brain; they bring the brain signals, amplified, to their screens. When no signals are present, there is nothing to see; but when the brain is active, the tubes light up, and the display becomes "an enchanted loom where flashing shuttles weave a dissolving pattern: always a meaningful pattern but never an abiding one." Sir Charles Sherrington's poetic image describes exactly the impression these scopes give. An automatic camera records snapshots of these scenes, transforming into frozen vectors the procession of illuminated butterflies which recalls the passionate Psyche of the classic Mind.

The display tubes are arranged behind a plastic screen mapping the head as seen from above [*photograph on opposite page*]. Each tube is a sort of clock face too, for in each the electron beam which the brain signals turn on and off is formed by special circuits into a rotating line or spoke, like the sweep hand of a radar receiver. All these electronic clock hands turn at the same speed, and the speed is controlled either by the experimenter or by the subject's brain itself. When the operator controls the speed, the time scale is ordinary clock time; when the subject's brain controls it, the time is "local" time—the time scale of that part of the brain at that moment. The varying relation between brain time and standard time shows as a blurring of the needle on a meter which records the time of each revolution of the hand. Thus parts of the brain that keep the same time can be picked out quite easily, and the signals they exchange can be distinguished from the gossip and backchat of bystanders and the welter of routine traffic. Since the instrument can also deliver stimuli in various patterns at selected times, the marriages of new sensations to pre-existing activity can be watched as an electric concordance of great variety and beauty.

When we began to use this machine, we found the time maps hard to understand. But gradually the new code has begun to penetrate our thick heads, and much of what was quite bewildering in the ordinary brainprints now seems to be taking on a new form and luster. When the brain is receiving a time pattern of visual signals (for example, a series, or group, of flashes, then an interval, then another group and so on), the pattern often is "dissected"; adjacent areas respond to selected parts of the pattern in sequence, as if some scanning process is "turning on" one part of the brain after another. In areas distant from the visual region, the responses are recombined in an arrangement resembling the original pattern.

Learning

These two effects—dissection and remote resynthesis—seem to solve partly two of the main mysteries posed by the brainprints, namely, the function of the alpha rhythms and the widespread effects of flicker stimulation. In most normal subjects activity appears in the temporal or the frontal lobes, which are remote from the visual projective area, mainly when the visual pattern is novel or interesting. There the pattern may be complete again, sometimes simplified or even abstracted, as it were, shorn of irrelevant variations and inconsistencies. In the temporal lobes, when the stimulation ceases the pattern hangs on—a phantom of meaning which as the seconds pass dwindles into the nothingness of all forgotten things. In subjects too experienced in these trials no hint of these strange processes is seen. The processes are not the well-worn trade routes of automatic life; rather they are the speculative, adventurous machinery that guides the living brain to matching within itself the indifferent or hostile change and chance of the world it must manipulate.

This great problem of how a brain can decide that an association or coincidence of events is not mere chance was considered in a previous article ["A Machine That Learns," by W. Grey Walter; SCIENTIFIC AMERICAN, August, 1951]. The suggestion made there was that for even the most rudimentary learning by association seven distinct operations must be performed to decide whether one series of events implies another. The implications of this hypothesis were illustrated by the simple electronic learning circuit named *Machina docilis*, which was developed in the hope of explaining, or at least describing more coherently, the features of brain function which the Toposcope was beginning to illuminate. *M. docilis* can learn only one simple lesson. In the human brain no bounds can yet be set for learning, but on the lowest level we are beginning to have some confidence that the mechanisms of understanding are not unimaginably beyond our understanding.

The pictures of brain response produced by the Toposcope indicate that, as required by theory, signals entering the brain are subjected to considerable processing before they reach the primary receiving areas. Somewhere in the middle of the head is a diffuse foliage of nerve cells and tendrils that picks up from the stream of incoming messages a series of hints that "something has happened." This information, crude, unspecific but emphatic, is broadcast to many distant regions. The effect is to alert the whole brain. When the situation is novel and the intensity of the signals high, the widespread responses are almost in the nature of an alarm—"anything may happen." But, as we have seen, familiarity breeds indifference; the brain learns to assess the message and to file it away unless in fact it turns out to signal some important event. In the course of time, after many trials and rehearsals, the brain establishes the meaning and importance of new messages.

In the article on *M. docilis* it was suggested that this assessment of importance can be accurate only if the brain operates as a statistical computer. We conjecture that the living brains we are examining with our recording machine are engaged in working out as best they can the chances that what we are doing may have some meaning—some relevance to the problem of their survival. When, in moments of relatively lucid experimenta-

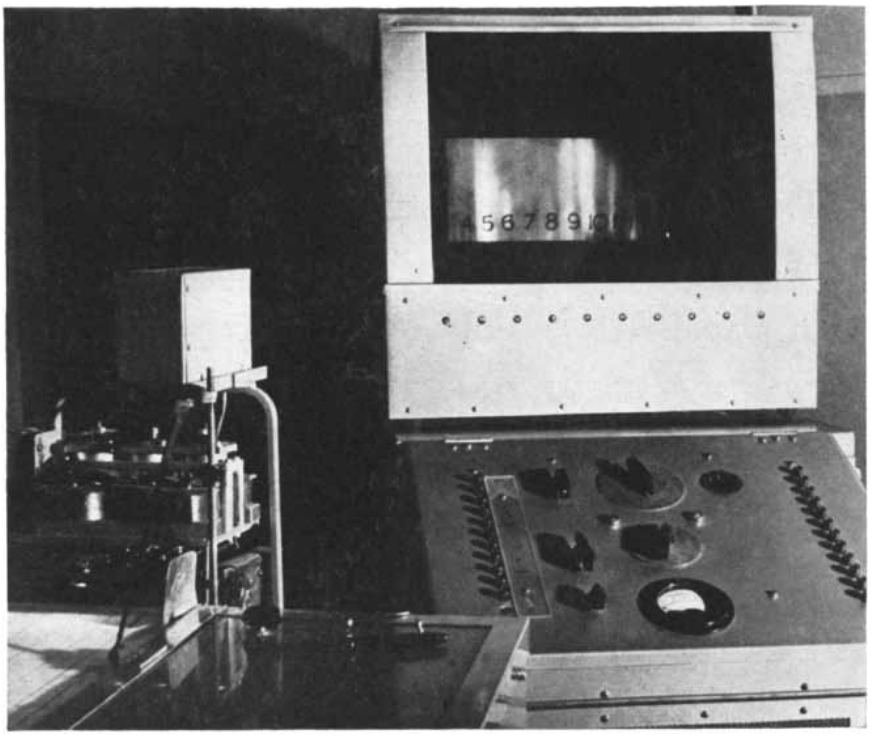
tion, we hit upon a message which apparently does convey some meaning, then the texture of the electric fabric woven before our eyes acquires indeed a meaningful pattern. In those of our subjects who suffer from seizures or disorders of consciousness during flicker, the "pari-mutuel" within the brain jumps the lines and throws out a wild and vulgar guess, as though everything meant anything. This conclusion is so utterly inconsistent with the continuation of life that only a general shutdown can avert catastrophe, and the patient lapses into a daze.

Topsy's Promise

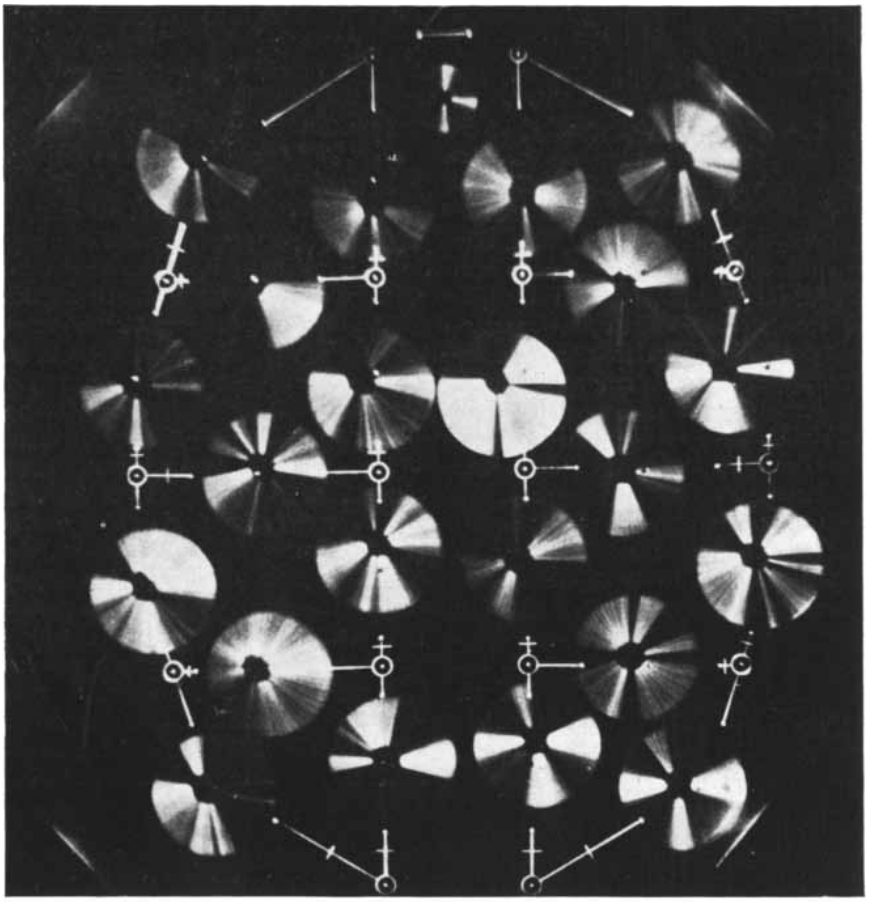
The application of these methods and theories to clinical problems is becoming a serious preoccupation. Mental or nervous disorders which are undetectible in conventional brainprints often show up markedly when studied with the Toposcope during stimulation or excitement. One significant clue is the length of persistence of an electrical pattern after the stimulus is terminated. In some people whose thinking is confused and incoherent this "memory" time seems to be 10 times as long as in ordinary folk. When a succession of different patterns is presented to them, the brain activity shows a "double-exposure" effect—a pastiche of surrealistic phantoms and grotesques.

In a few cases we have been able to probe with the Toposcope some of the deeper levels of the brain, when surgeons have had to remove the upper part of the brain of a patient who has suffered some serious brain injury or disease. As we should expect from theory, the activity from the deep brain is simpler, more urgent, more evanescent than that from the upper regions. Most important of all, there is almost no trace of "memory" or persistence of a stimulated pattern when the upper crust of the brain is missing.

With the united efforts of the many laboratories now mobilized for these studies we can plan our campaign for investigation of the living brain with more confidence than ever before. The tactics and strategy of this great effort toward self-understanding were discussed in Boston last summer at the Third International Congress of Electroencephalography, where several hundred enthusiasts gathered to dispute such observations and theories as have been outlined here. No doubt in a few years both our machines and our notions will seem as crude and as incoherent as Berger's first articles did a generation ago.



WAVE ANALYZER of the Burden Institute not only traces a curve (*lower left*) but also projects a luminous image (*upper right*). The vertical bands on the screen indicate the frequency components. This image indicates that a beat of 10 cycles per second is strongest.



TOPOSCOPE DISPLAY is an array of cathode-ray tubes. The lines on the transparent screen in front of the tubes indicate the linkage of each tube to the electrodes on the head of the subject. The image on each tube is made by a luminous line sweeping like the hand of a clock.

THE BOILING OF LIQUIDS

The phenomenon is studied because of problems in the transfer of heat from solids. It seems that the familiar burbling of water in a teakettle is only one of three ways in which liquids can boil

by J. W. Westwater

It is a curious fact that some of the most familiar phenomena in nature are among the least understood. Consider the boiling of water. Man's acquaintance with this phenomenon is at least as old as his discovery of fire, yet until very recent years no one had ever made a serious study of how and why liquids boil. It has turned out that boiling is far more complex than anyone had imagined.

In 1934 Shiro Nukiyama, a Japanese, carried out a simple experiment. He submerged a fine platinum wire in water and heated the wire with an electric current to produce boiling. He discovered that the rate of heat flow from the wire to the liquid increased steadily as he raised the temperature of the wire until its temperature reached 150 degrees centigrade. Then a totally unexpected thing happened. When he increased the current slightly at that point, the wire temperature (calculated from its electrical resistance) jumped suddenly to about 1,000 degrees C. Either at 150 or at 1,000 degrees the wire made the water boil. But it was simply impossible to raise the wire temperature to just a few degrees beyond 150.

Nukiyama now tried wires of nickel and of a nickel-chromium alloy. When their temperature made the jump beyond 150 degrees, the wires melted, these metals having lower melting points than platinum. The boiling, of course, then came to a halt.

This temperature jump was puzzling. Why should it be easy to boil water with a wire at 150 degrees but apparently impossible to boil water with the same wire at 160 degrees? Nukiyama went back to the platinum wire to look more closely into the boiling at high temperature. He was able to reduce the temperature of the wire gradually down to 300 degrees. Above that level any rise in the temperature caused an increase in the heat flow, and *vice versa*. This seemed normal and in agreement with intuition. But any attempt to reduce the wire temperature slightly below 300 degrees met with failure; it then dropped suddenly below 150 degrees.

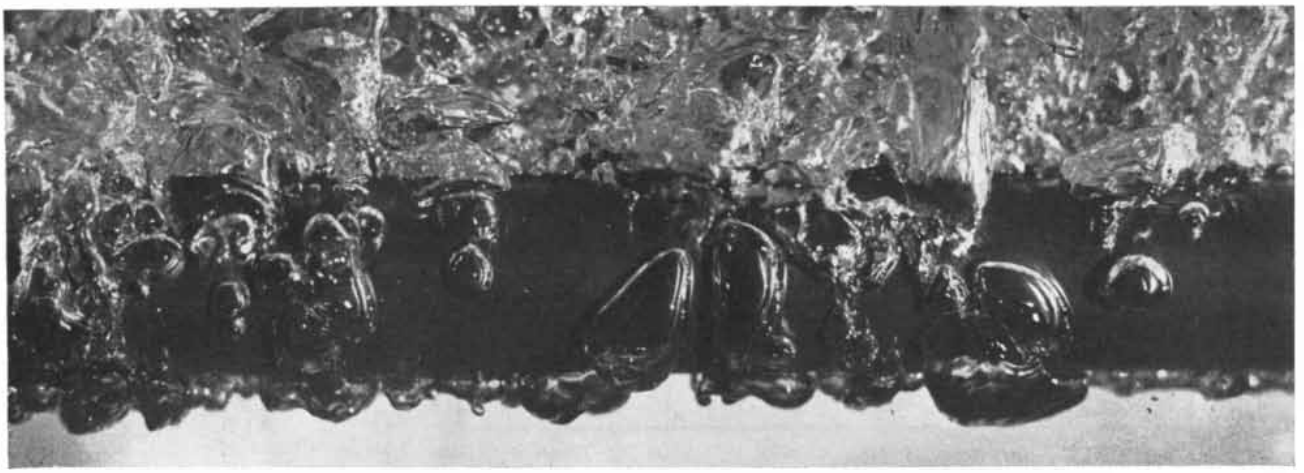
Nukiyama concluded that one type of boiling occurred below 150 degrees and another above 300 degrees, and he guessed that a third, abnormal kind of boiling might take place in the region between 150 and 300 degrees. It was clear that if the middle type did exist, it would have a peculiar characteristic: any increase in the metal temperature would cause a *decrease* in the heat released. This is certainly contrary to intuition.

The mystery has recently been pursued further in our laboratory at the University of Illinois with support from the National Science Foundation. It has attracted a lively practical interest with the advent of nuclear reactors, jet engines and rocket motors. A nuclear reactor, for example, requires the removal of large amounts of heat from a relatively small reaction zone. The use of boiling liquids as coolants appeals to engineers because of the rapid rate at which such a liquid can absorb heat. One square foot of a hot solid at 145 degrees C. can transfer to boiling water as much as 400,000 British thermal units per hour, enough to generate about five tons of steam per day. This is about 10 times the rate at which heat can be transferred to nonboiling water and about 100 times the rate to circulating air. Progress in the study of boiling has been stimulated greatly by the promise of quick application of new information.

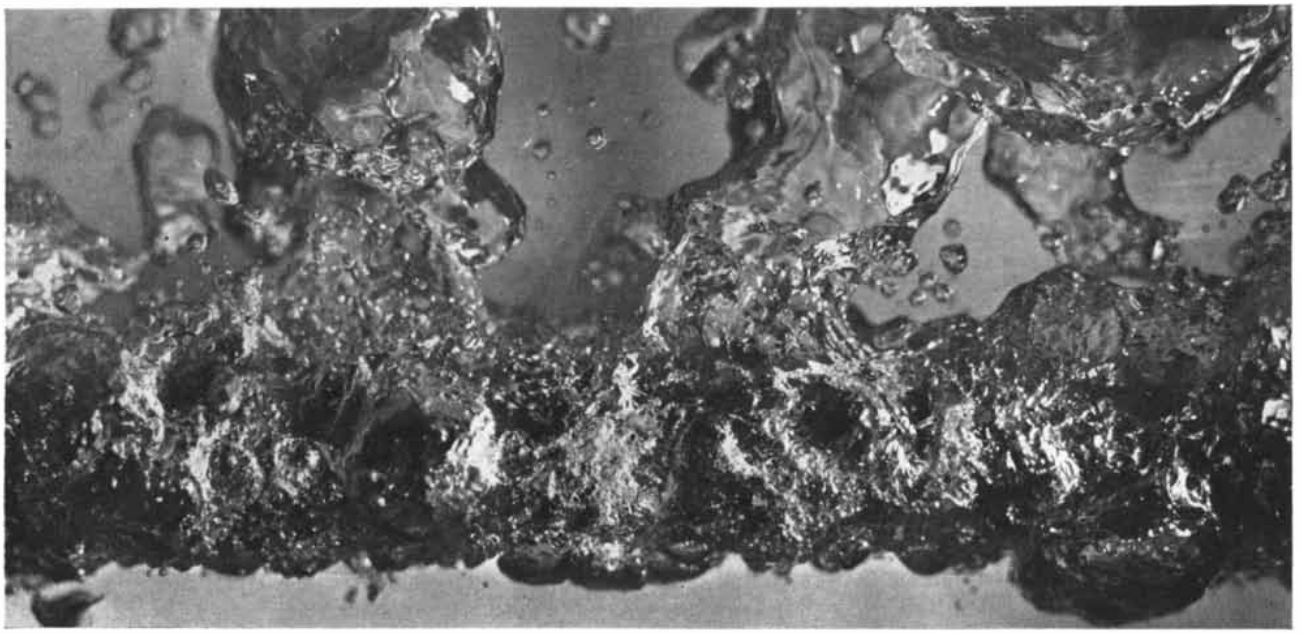
Nukiyama was quite correct: there are indeed three types of boiling. They are usually called nuclear, transition and film boiling. To the eye they are distinctly different. An experienced worker can even distinguish them by ear. In a typical test the noise rises from 2 to 18 and then to 26 decibels as the boiling progresses from nuclear to transition to film boiling.

The appearance of these boiling phenomena is shown in the photographs on the opposite page, made by J. G. Santangelo at the University of Illinois. The exposures were at one millionth of a second and were obtained by the flash-tube technique. Methyl alcohol was selected as the boiling liquid so that all three types of boiling could be obtained within the range of temperatures available with laboratory steam heat (100 to 170 degrees C.) The heating element was a copper steam tube three eighths of an inch in diameter. The choice of steam heat was important, because transition boiling happens to be quite stable with a steam tube but is very unstable with an electrically-heated element.

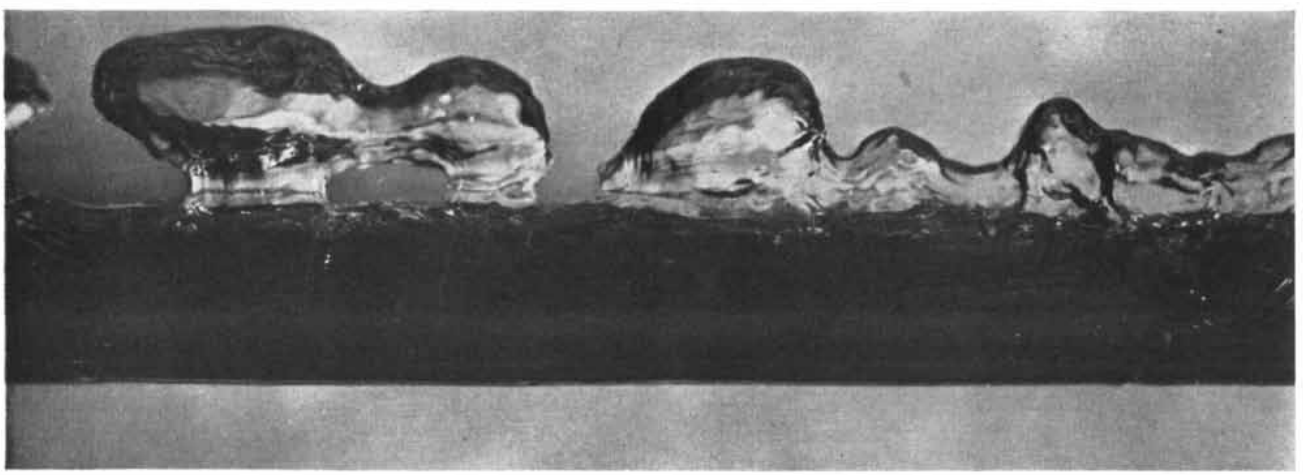
The copper tube was 3½ inches long and was of bayonet construction. It was placed horizontally in a flat-sided glass boiler containing about one gallon of methyl alcohol. As the alcohol boiled, the vapor passed to a water-cooled condenser; from there the condensed liquid returned continuously to the boiler. The amount of heat transferred was calculated from measurements of the rate of steam condensation in the boiler tube, and there were check measurements of the heat absorbed by water in the condenser and of the temperature of the al-



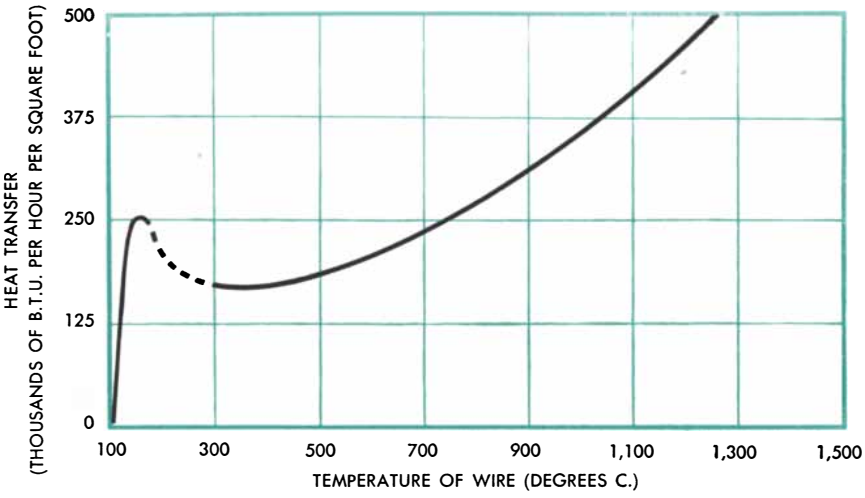
NUCLEAR BOILING is photographed at a millionth of a second in a glass tank filled with methyl alcohol. Running across the tank is a copper tube heated by steam. The bubbles of alcohol vapor form repeatedly at the same points on the surface of the tube.



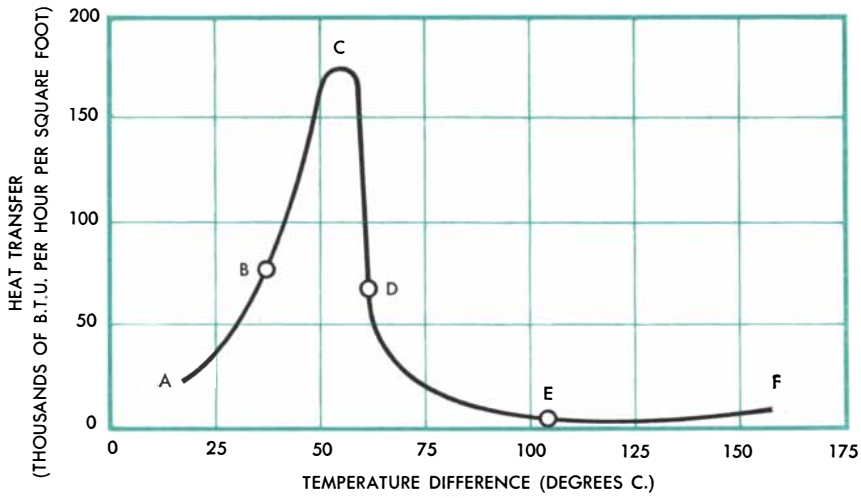
TRANSITION BOILING occurs at temperatures higher than those which cause nuclear boiling. Here slugs of alcohol vapor form explosively, and the surface of the tube is entirely blanketed with vapor. One slug of vapor surges away from the tube at lower right.



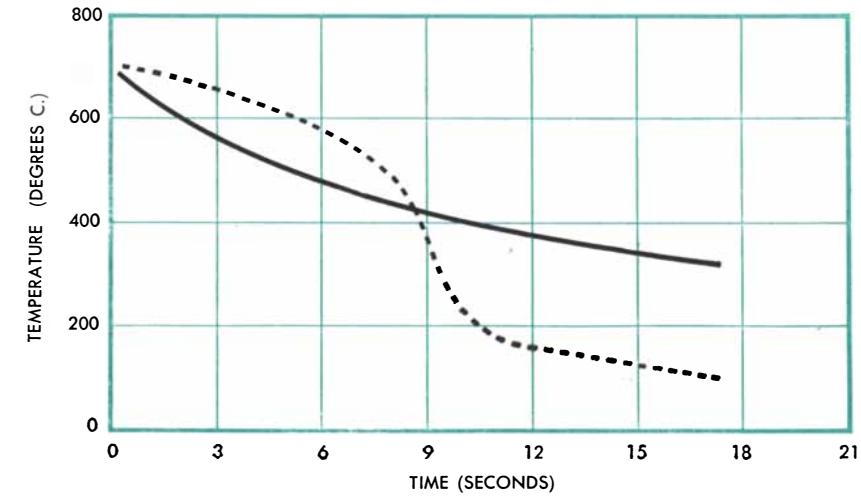
FILM BOILING occurs at temperatures higher than those which cause transition boiling. Here the tube is surrounded by a transparent film of alcohol vapor. At the top of the tube the vapor has formed into a wavy "rod" about to break into a row of bubbles.



WATER CURVE was plotted by the Japanese worker Shiro Nukiyama. He measured the amount of heat transferred from an electrically heated wire to boiling water. When he tried to heat the wire beyond 150 degrees C., its temperature jumped, skipping dotted section.



METHYL ALCOHOL CURVE was plotted by the copper-tube technique. Nuclear boiling is A to C; transition boiling, C to E; film boiling, E to F. Photographs on preceding page were made at B, D and E. The temperature difference is between tube and boiling alcohol.



METAL CURVE can be explained by the three different kinds of boiling. The solid curve represents the rate of cooling of a one-inch steel bar quenched in a nonboiling liquid. The peculiar dotted curve represents rate of cooling of a bar quenched in a boiling liquid.

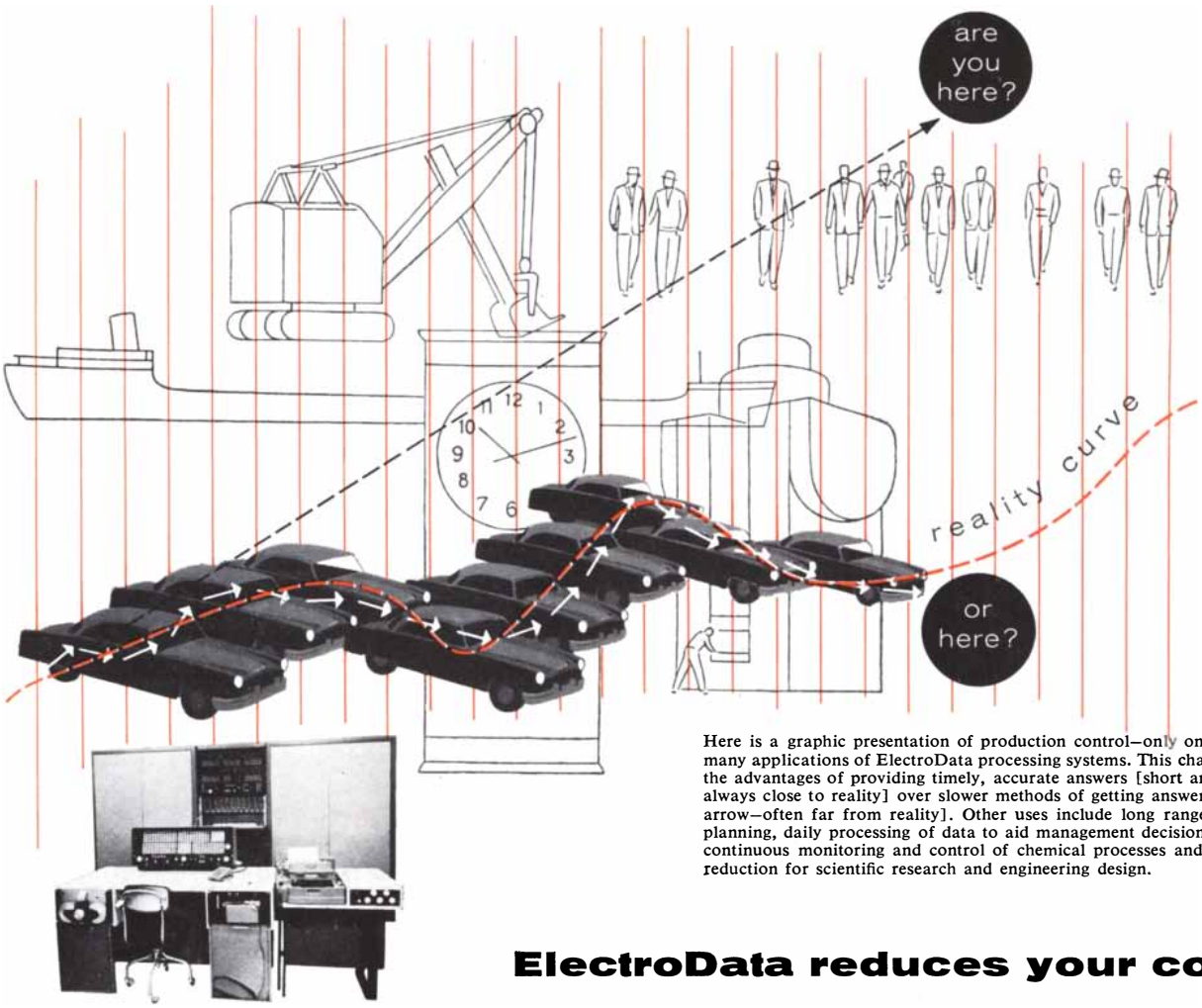
cohol leaving the condenser. The steam temperature was calculated easily from the measured steam pressure. The alcohol boiled at its normal boiling point, 64.7 degrees C.

Nuclear boiling is the usual boiling that occurs in a teakettle. Bubbles form on the hot surface of the kettle bottom with great speed. As soon as one bubble breaks loose, a new one grows at precisely the same point on the hot solid. The solid seems to be peppered with active points. Bubbles keep forming repeatedly at these points, even though near-by areas of the solid may be clean and free of bubbles. The amount of heat transferred to the liquid depends on the number of active points. An increase in the metal temperature activates new ones. A decrease causes some of the old points to cease functioning. No one knows just what an active point is. Suggestions have been made that it may be a tiny impurity on the solid or a microscopic sharp-point roughness of the surface or perhaps a tiny cavity (containing adsorbed inert gas) in the solid.

In the case of methyl alcohol, when the temperature difference between the solid and the liquid is 39 degrees C. each active point emits bubbles at the rate of about 17 per second. This of course is not evident to the unaided eye. The fact was discovered from close-up motion pictures taken at 4,000 frames per second and projected at 16 frames per second. This technique gives a slowdown in the action by a factor of 250 to 1. The fast emission of bubbles results in violent agitation of the liquid. Undoubtedly the agitation assists the heat transfer and is the principal reason why nuclear boiling is such an efficient way of transferring heat.

When the heat transfer is at a maximum rate, practically the whole surface of the hot solid is covered with active points and bubbles. The active points are so close together that occasionally the bubbles interfere with one another. The critical temperature difference at which the maximum heat flow occurs is 57 degrees C. for methyl alcohol boiling on hot copper: for other liquids and other hot solids the value varies from about 10 to 60 degrees. The value depends on the liquid, the metal, the surface smoothness of the metal, the pressure and other factors.

When the temperature difference is increased slightly beyond the critical value, a dramatic change occurs. The rate of heat transfer drops considerably,



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and the boiling becomes noticeably louder. High-speed motion pictures show a series of small explosions occurring along the solid surface. In methyl alcohol at a temperature difference of 74 degrees the bursts occur 84 times per second per inch of length of tube (along the visible, photographed side of the tube). The bursts are at random locations; active centers no longer exist. The hot solid is now entirely blanketed with vapor, and the liquid no longer touches the solid at any place. The miniature explosions of newly created vapor keep blasting the surging liquid away from the metal. Each slug of vapor grows to its full size in about three thousandths of a second; in that time it pushes the liquid about four millimeters away from the solid. Then, after the velocity of the moving vapor has been slowed down by friction with the surrounding liquid, the vapor slug ruptures, and bubbles rise from it to the liquid surface.

This is the transition type of boiling. The great difference between nuclear boiling and transition boiling is that the former rapidly generates uniform bubbles from specific nuclei, while the latter exhibits a random generation of bubbles by sudden bursts. The reason the rate of heat transfer drops as boiling enters the transition region is the insulating blanket of vapor on the hot solid. The blanket begins to form when the temperature difference rises slightly above the critical point and grows thicker as the temperature is increased.

Eventually the blanket becomes so thick that it smothers all vapor bursts. Now begins the final phase—stable film boiling. Heat transfer and vapor generation fall to their lowest values. For methyl alcohol the minimum heat transfer is only 3 per cent of that at the peak of ordinary (nuclear) boiling. In other words, the heat given off from the solid at 122 degrees is more than 30 times as great as that at 165 degrees.

It is clear now why an electrically heated wire submerged in a boiling liquid may suddenly burn out. When the critical temperature difference is passed, the heat absorption by the liquid drops swiftly to a small percentage of its prior value. Meanwhile the electric current continues to generate heat in the wire at the same rate as before. High heat input and low heat output result in an accumulation of heat in the wire.

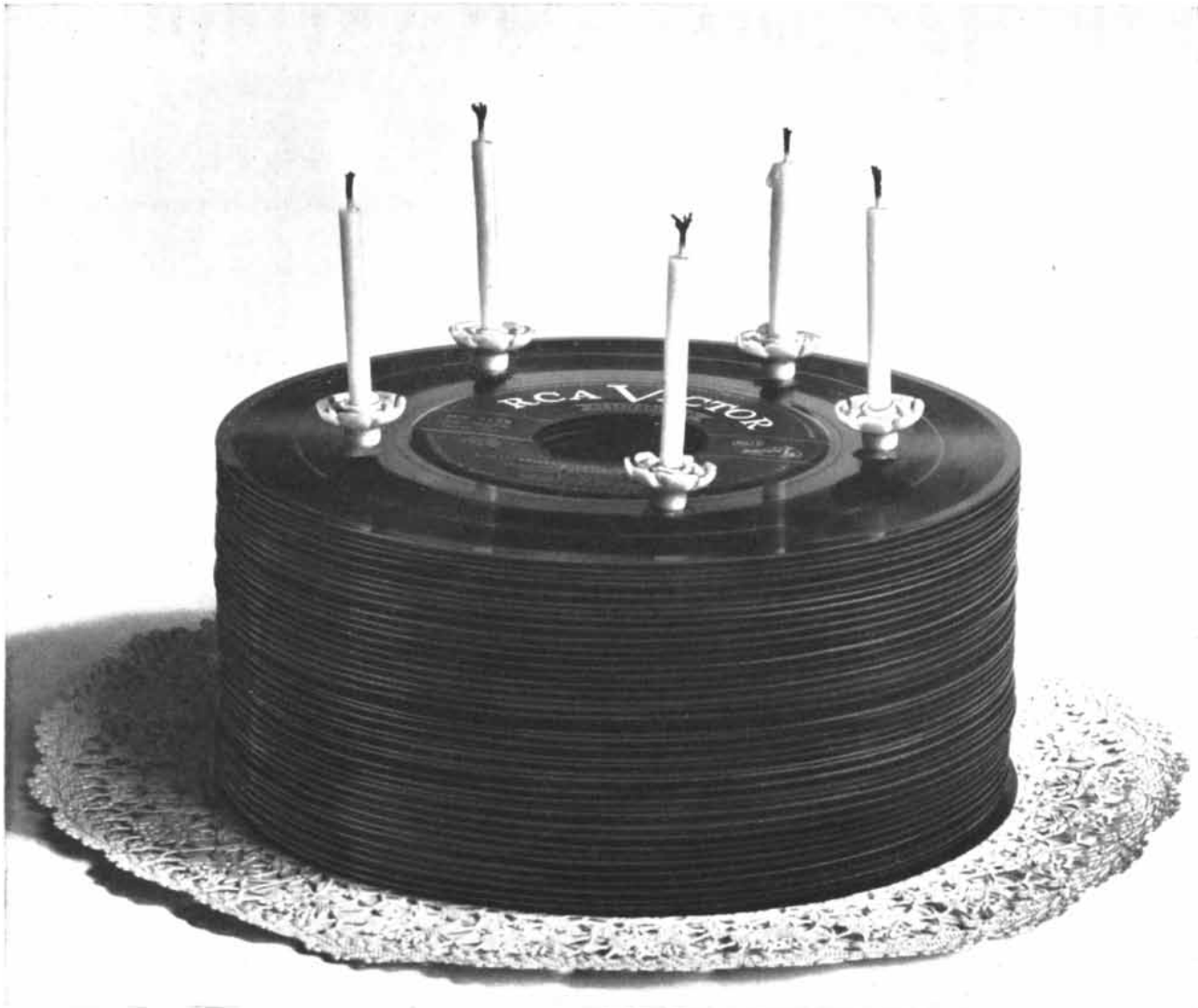
In film boiling no explosive bursts can be seen. A loud, drumlike noise rumbles from the liquid. Its dominant tone is at 25 to 30 beats per second. Through the stable layer of vapor, which completely blankets the solid surface, heat passes to the liquid by conduction and radiation. Convection probably is negligible. New vapor is formed only at the vapor-liquid interface, not on the surface of the solid. It flows to the top of the boiler with a gentle wave motion—a steady series of ripples passing at a rate as high as 74 per second.

If the vapor is allowed to accumulate, eventually a rodlike mass of vapor is formed along the top of the tube. The rod is smooth at first, but gradually a series of peaks, about equally spaced, appears in it. These nodes break off simultaneously along the entire tube, and large bubbles rise side by side in a row. In methyl alcohol at a temperature difference of 102 degrees C. a vapor rod forms and breaks at intervals of about six hundredths of a second. The bubble sizes (about a third of an inch) and spacings (half an inch apart) are surprisingly uniform. Oddly enough, in every second rank the bubbles arise at what were spaces in the rank before; the effect is that of a parade in which the even-numbered rows of marchers are displaced sideways by a half-space.

Film boiling is the type that occurs when a drop of water falls on a red-hot stove. The drop rolls about noisily, but it evaporates slowly. A drop on a moderately warm stove boils in nuclear fashion and evaporates much more rapidly.

All three types of boiling occur when a red-hot metal is quenched in water. The metal first cools slowly, then rapidly, then slowly again. The boiling goes through the three stages in the reverse of the usual order: film boiling comes first, then transition boiling and finally nuclear boiling, when the solid has been cooled to below the critical temperature difference and proceeds to lose heat most rapidly. After boiling ceases, the last cooling is by natural convection.

To sum up, nuclear boiling is marked by large rates of heat transfer and the rapid formation of bubbles from fixed points. Transition boiling exhibits a poorer heat transfer and random bursts of vapor. Film boiling shows the poorest heat transfer and a complete blanketing of the hot solid with a film of vapor. The best heat transfer is obtained at the critical temperature difference, which is the dividing line between nuclear and transition boiling. At an extremely high temperature difference a solid can transfer a great deal of heat to a liquid by means of radiation, but that is another story.



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FERTILIZATION AND ANTIBODIES

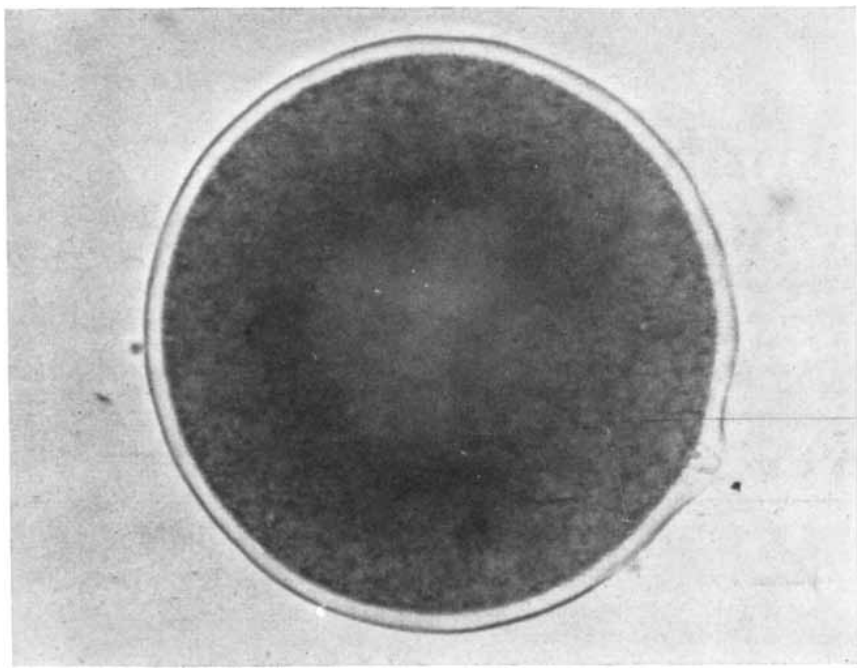
What is the chemical basis for the union of a sperm and an egg? A wide variety of experiments indicates that the event resembles the neutralization of a disease-producing antigen by an antibody

by Albert Tyler

The union of an egg and a sperm is strikingly like several other phenomena in the realm of life at the microscopic level. Think of a white blood cell engulfing a microbe, a virus "fertilizing" a bacterium, a parasite setting up housekeeping in a host cell. The resemblances among these events are not just superficial or accidental. Although their final results differ, all the processes have certain features in common: two motes of living matter interact or combine chemically to create something new. In a general way we can think of all these interactions as diverse expressions of one basic biological transaction—the antigen-antibody reaction.

The antigen-antibody idea has become a widely useful concept in biology. People usually think of antigens as substances derived from an infecting organism and of antibodies as substances manufactured by the body to attack or neutralize the invader. But the concept has now been carried much further. Sometimes antibodies work in such a way as to produce an ailment rather than prevent one; combining with pollen or some other allergy-inducing substance, they initiate an allergic reaction. Some antibodies are natural, ever-present components of the body; for instance, if A-type blood is injected into an individual whose blood is type B, the red cells of the injected blood are agglutinated by "antibodies" in the plasma of the B blood. These antibodies are not formed in response to any stimulus from outside; they owe their existence to the individual's genes.

Progress in man's understanding of his world comes by looking at old things in new ways. Here certainly is an inviting new approach to the ancient problem of the fertilization of the egg. Studies of that process from the antigen-antibody point of view have been highly enlightening, not only about fertilization but also about many other life processes.



EGG AND SPERM of the marine worm *Urechis caupo* are shown at the moment of fertilization. The head of the sperm, already engulfed by the translucent fertilization membrane of the egg, is visible at the lower right. The detached midpiece and tail are barely visible outside the bump in the membrane. This photomicrograph enlarges the egg 1,500 diameters.

It was the noted Woods Hole embryologist Frank R. Lillie who, some 40 years ago, first discovered that substances of the egg and sperm combined in a kind of antigen-antibody reaction. One very characteristic feature of such a reaction is that it causes cells or particles to clump (agglutinate). Lillie found that when he put the sperm of sea urchins in sea water which had been in contact with sea-urchin eggs, the sperm clumped. He concluded that the eggs had released an agglutinating substance, which he named fertilizin.

Lillie's discovery was not widely followed up at the time, but within the past decade biologists have returned to it. We have established that fertilizin is the material making up the gelatinous coat of the sea-urchin egg. When the eggs stand in sea water, the coat gradually dissolves. Fertilizin combines with a substance called antifertilizin on the surface of sperm, and when it does so in solution, the sperm clump together.

The sperm-agglutination reaction is now known to occur in many species of animals, including rabbits, mice and rats. Some species of animals fail to show the reaction, but this does not necessarily

mean their eggs lack a fertilizin which combines with sperm. According to the modern concept of serological agglutination reactions, developed by J. R. Marrack in England and by Michael Heidelberger and Linus Pauling in the U. S., mass clumping can occur only when the antibody and the antigen possess two or more reactive sites (*i.e.*, each is multivalent). Obviously univalent molecules cannot bind groups of molecules together.

The concept of univalent antibodies explains why the fertilizins of some species of animals and certain other antibodies, such as those in most types of anti-Rh blood, fail to cause agglutination of cells. These substances can, however, be made to produce clumping by adding certain proteins or amino acids as reagents. Contrariwise, an agglutinating type of fertilizin can be converted into a non-agglutinating form by treatment with ultraviolet irradiation, X-rays or enzymes that break up proteins.

The role of the egg's fertilizin and the sperm's antifertilizin is to provide a combining reaction which enables the sperm to attach itself to the surface of the egg. The reaction is highly specific; the fertilizin of one species of animal will not react with the antifertilizin of another species, except that a weak reaction may occur when the species are closely related. That seems to be one of the main reasons why different species usually cannot crossbreed; the sperm cannot even get a foothold on the egg.

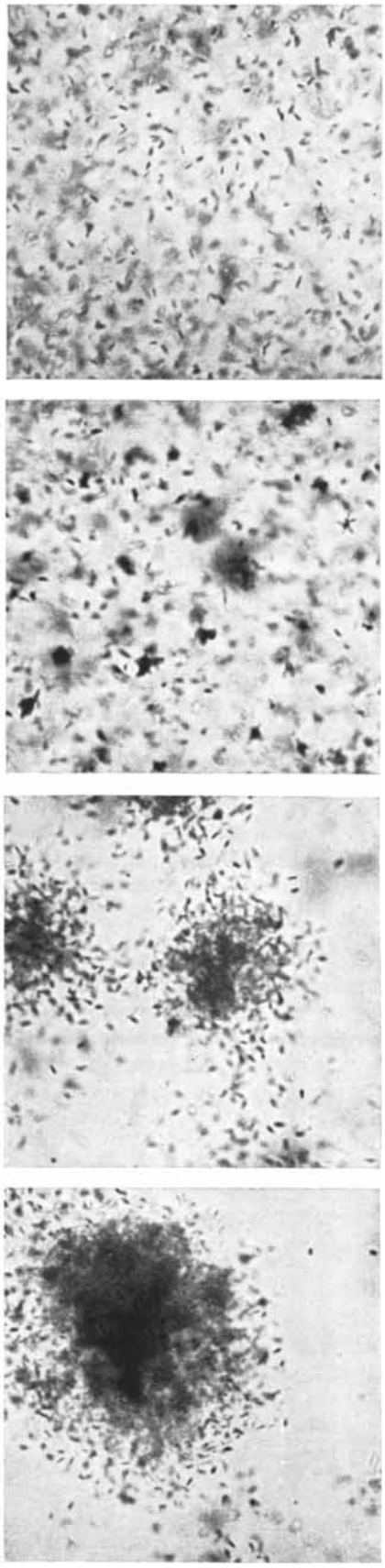
No fertilization is possible unless fertilizin in the surface coat of the egg reacts with antifertilizin on the surface of the sperm. As we have noted, fertilizin in solution causes sperm to clump. Once this has happened, the sperm lose the power to fertilize; even if they separate again after a time, as they do in many species, they cannot attach themselves to an egg because their antifertilizin is already tied up by fertilizin. Since there is always some dissolved fertilizin in the liquid around eggs, free sperm might never get to the eggs, but nature has taken care of the problem by arranging that animals produce a great plethora of sperm. The excess sperm mop up the dissolved fertilizin, so that at least one unneutralized sperm is able to reach the egg.

All this has an interesting bearing on virus diseases. In order to infect a cell a virus must first attach itself to the cell's surface by reaction with a receptor substance on the cell. Investigators have experimented with solutions of such substances to see if they can block viruses from adhering to cells. They have already succeeded in blocking bacterial viruses and there are promising indications that they will soon succeed with animal viruses.

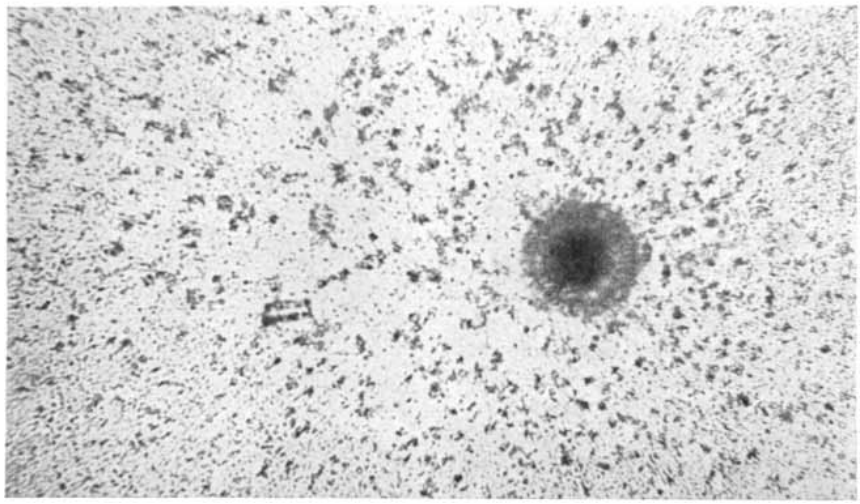
After a sperm has won its hold on the egg surface, it may have to breach a tough membrane to get inside. In the case of mammals, the cells of the egg membrane are held together by a glue-like substance called hyaluronic acid. The sperm produces an enzyme, hyaluronidase, which dissolves the glue.

Now hyaluronidase is not peculiar to sperm; it has been identified in many other cells, notably bacteria. In 1928 the bacteriologist Francisco Duran-Reynals, then at the Rockefeller Institute for Medical Research (he is now at Yale University) was experimenting with injections of extracts of testes. He found that when the extracts were injected into the skin of an animal along with an indicator (*e.g.*, India ink particles) the indicator spread through the animal's tissue much more widely than it otherwise would have done. This was later shown to be due to the fact that hyaluronidase in the extract dissolved the hyaluronic acid between the skin cells. It was discovered that many bacteria, snake venoms and other toxic materials contained this enzyme. The ability of various pathogenic organisms to invade tissues and spread their infection is correlated with their ability to produce hyaluronidase. In other words, spermatozoa use the same kind of enzyme in invading the egg as bacteria do in spreading infection through the tissues.

Chemically the substances we have been considering—fertilizin, antifertilizin and cell-membrane dissolvers such as hyaluronidase—are related to one another and to certain other special materials in the body. They are all large protein molecules. The fertilizins belong to the special class called glycoproteins—proteins containing sugars. This class of substances is assuming increasing importance in biology. It includes, for example, the pituitary gonadotropic hormones, the antigens contained in the A, B and O types of human blood, and the receptor substances by which the influenza virus and others attach to cells. The human blood-group substances contain the rather special simple sugar fucose. Fertilizins of sea urchins also generally possess the same sugar. Whatever the explanation may prove to be, it certainly is striking that much the same type of substance is involved in such



SPERM of the giant keyhole limpet clump together when treated with a solution of fertilizin from limpet eggs. These photographs were made over a period of one minute.



RABBIT SPERM near a rabbit egg are clumped by fertilizin from the egg. The sperm farther away have not clumped because the fertilizin has not diffused out to them.

diverse situations as the human blood-group reactions, infections by viruses and the agglutination of sea-urchin sperm.

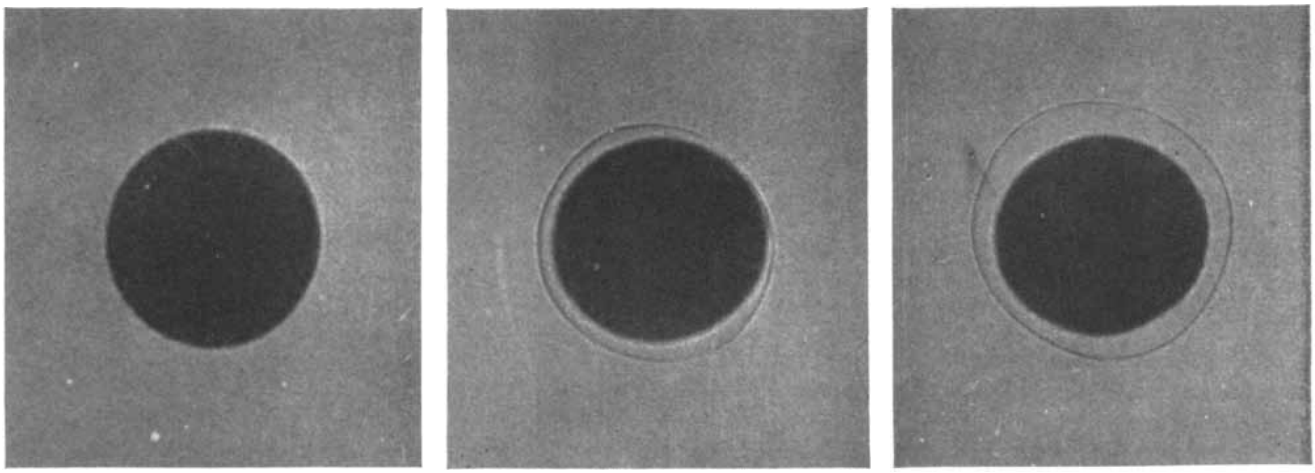
Another surprising discovery is that antifertilizin is found not only in sperm but in the interior of the egg as well. The antifertilizin there combines with fertilizin in the same antigen-antibody manner as does the antifertilizin of sperm. A solution of it will agglutinate eggs and form a precipitation membrane on them just as sperm antifertilizin does. Chemically egg antifertilizin differs in several properties from that obtained from sperm, but both evidently possess the same kind of reactive groups.

The finding of an antifertilizin within the egg has implications of broader significance than the problems of fertilization as such, and some of these are now being explored. It is a remarkable fact that a single cell should contain within itself two substances which react with each other in the manner of an antigen and an antibody. There is evidence that this situation is true not only of the eggs of sea urchins but also of various other normal cells, tissues and organisms.

One example is the red cells of human blood. Very often an individual's blood is found to contain substances which agglutinate his own red cells. Usually they can act in this way only at below-normal temperature, but some of them also are active at body temperature. Because the agglutinating substances commonly appear in the blood during certain diseases (*e.g.*, virus pneumonia, trypanosomiasis, hemolytic anemia), it has been supposed that they are formed as a reaction to infection. But in the light of the finding that antigens and antibodies may occur normally in the same cell, it is more reasonable to surmise that these auto-antibodies are natural substances which are released by red cells when the cells are formed or when they die and which can react with material on the surface of red cells, causing them to clump. In diseases that increase the rate of turnover of red blood corpuscles, the agglutinating substances may accumulate in the blood instead of being eliminated as fast as they are formed; such a process could account for blood clots, the appearance of hemoglobin in the urine and other critical pathological conditions. When the auto-antibodies are of the kind that react only below body temperature, they may, of course, accumulate without apparent harm to the individual.

About 12 years ago the pathologists J. G. Kidd and W. F. Friedewald, then at the Rockefeller Institute for Medical Research, found another kind of auto-antibody in the normal blood serum of rabbits; that is, rabbits which had not been exposed to an infection that would evoke immunizing antibodies. Their serum reacted with extracts from the animals' own tissues in the manner of antigen and antibody. We can suppose that the auto-antibodies were normal material dissolved from the surface of the animals' tissue cells, and that the "antigens" with which they reacted were substances from the interior of the cells.

The Wassermann test used to diagnose syphilis may be another illustration of the same phenomenon. The antibody that is supposed to signalize a syphilitic infection is peculiar: it does not react with the syphilis spirochete itself but with certain fatty body substances. Immunologists have proposed various explanations of this situation, such as that these fatty substances resemble the spirochete's antigens or that they combine with spirochete substance to form antigens. We offer a different interpretation, namely, that when the spirochete destroys tissue, it liberates into the blood a protein and a fatty substance, which fit structurally like antigen and antibody.

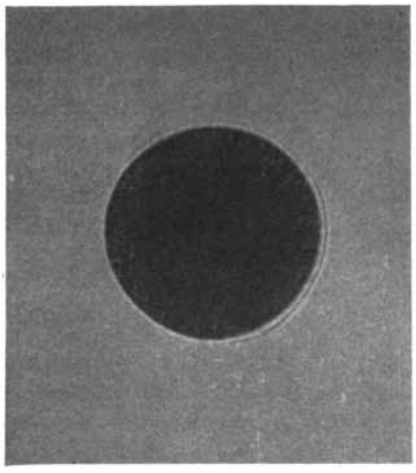


PRECIPITATION MEMBRANE forms on the surface of the gelatinous coat of a sea-urchin egg after the addition of a solution of antifertilizin derived from the sperm of the sea urchin. The photograph at left shows the untreated egg. The succeeding pictures were

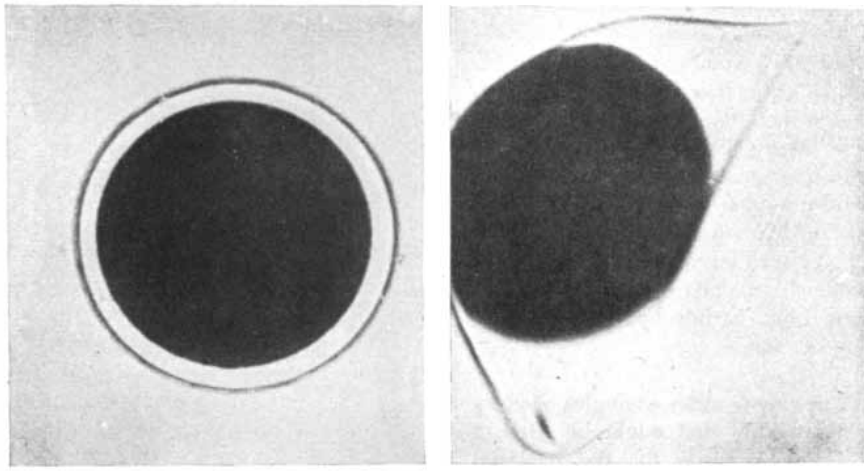
Because the fatty molecule is smaller than the protein, it is eliminated from the body more rapidly, and the protein "antibodies" remain in the circulation. Samples of the blood serum can then react with the fatty antigen in a test tube. If this theory is correct, other tissue-destroying agents besides the spirochete should produce the same kind of "antibody" in the blood. As a matter of fact, it is now well known that various other infections (malaria, leprosy, tuberculosis) result in false positive Wassermann reactions.

Of the many other examples of auto-antibodies that might be cited, a case can be made for the bacterial viruses. About 20 years ago the famous Australian virologist Frank Macfarlane Burnet showed that a solution of a substance from the surface coat of bacteria could inactivate viruses that attacked them. More recently André Lwoff of the Pasteur Institute in Paris has produced evidence that the bacterial virus is probably a modified form of a normal constituent of the bacterium itself ["The Life Cycle of a Virus," by André Lwoff; SCIENTIFIC AMERICAN, March]. This "provirus" can be activated by exposure of the apparently normal bacterium to certain drastic treatments, such as ultraviolet radiation. The virus particle then reacts with a surface substance of the bacterium.

The auto-antibody concept also could explain why venomous snakes and scorpions are immune to their own venom: they may possess a complementary, neutralizing substance. We have found that liver or blood extracts of the venomous lizard called the Gila monster will counteract its venom when injected into laboratory mice along with the venom. A tiny amount of Gila monster serum



made at 30 seconds, two minutes and three minutes after the addition of antifertilizin.

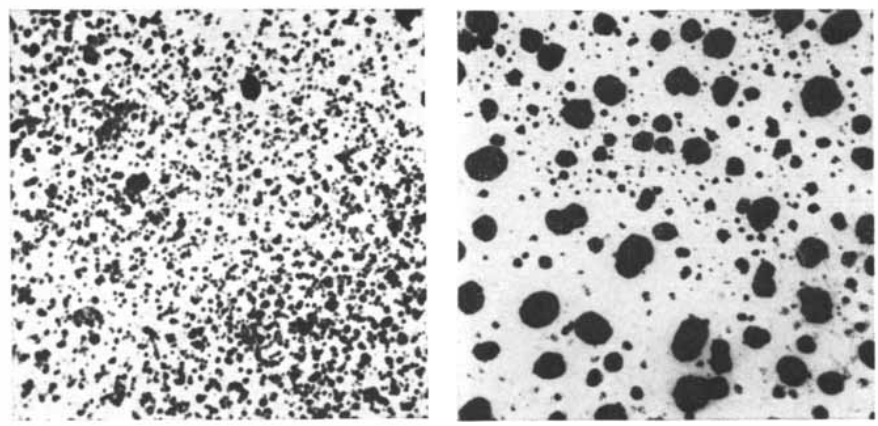


CELL MEMBRANE of an unfertilized egg of the giant keyhole limpet dissolves after it is treated with an extract of limpet sperm. The untreated egg is at left. The second photo-

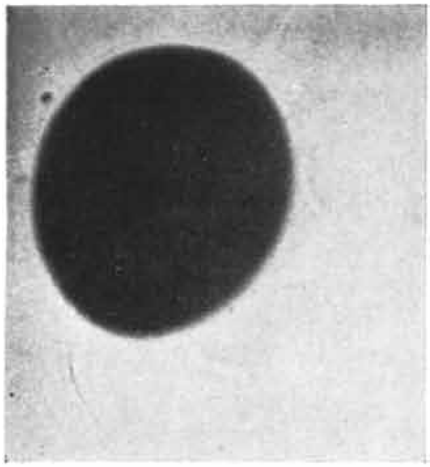
(about three hundredths of an ounce) neutralizes about 60 times the lethal dose of venom.

Naturally the auto-antibody concept suggests the possibility of fighting infections with substances extracted from the infecting organisms themselves. That subject is now being explored. Another aspect of the concept should be considered; namely, its relation to how antibodies are formed in response to infection. According to the present view, developed largely through the work of Felix Haurowitz of Indiana University, Stuart Mudd of the University of Pennsylvania and Linus Pauling of the California Institute of Technology, foreign antigens serve as templates for the construction of the antibodies complementary to them. That is, when an antigen enters an animal, it becomes incorporated into the cells that produce certain blood proteins, known as globulins, and changes the structure of the globulins so that they fit and can combine with the specific structure of the antigen. It follows that the proteins normally present at the globulin-manufacturing sites serve as templates determining the shape of the normal globulin, or auto-antibody. The specific form of these proteins of course is determined by the genes of the organism. We can, in fact, extend the auto-antibody idea to all cells and suggest that the large molecules which form the basis of their structure and function are made up of pairs of structurally complementary substances that act like antigen and antibody.

Plainly this view opens a new general outlook in fundamental biology and suggests new lines of research. For one instance, Melvin Spiegel of our laboratory has been investigating how cells stick together in forming an organism. It had been demonstrated that cells of sponges, after being separated from one another, can reassemble into complete, normal individuals. The reunion is high-



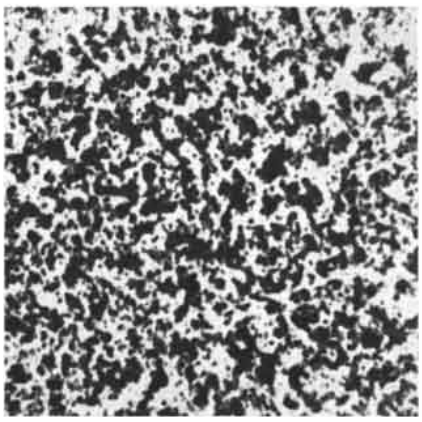
SPONGE CELLS in the photomicrograph at the left have been forced through a sieve to separate them. The second picture shows the cells in a solution of normal rabbit serum; after 24 hours they have begun to clump. The third picture shows the cells in a solution



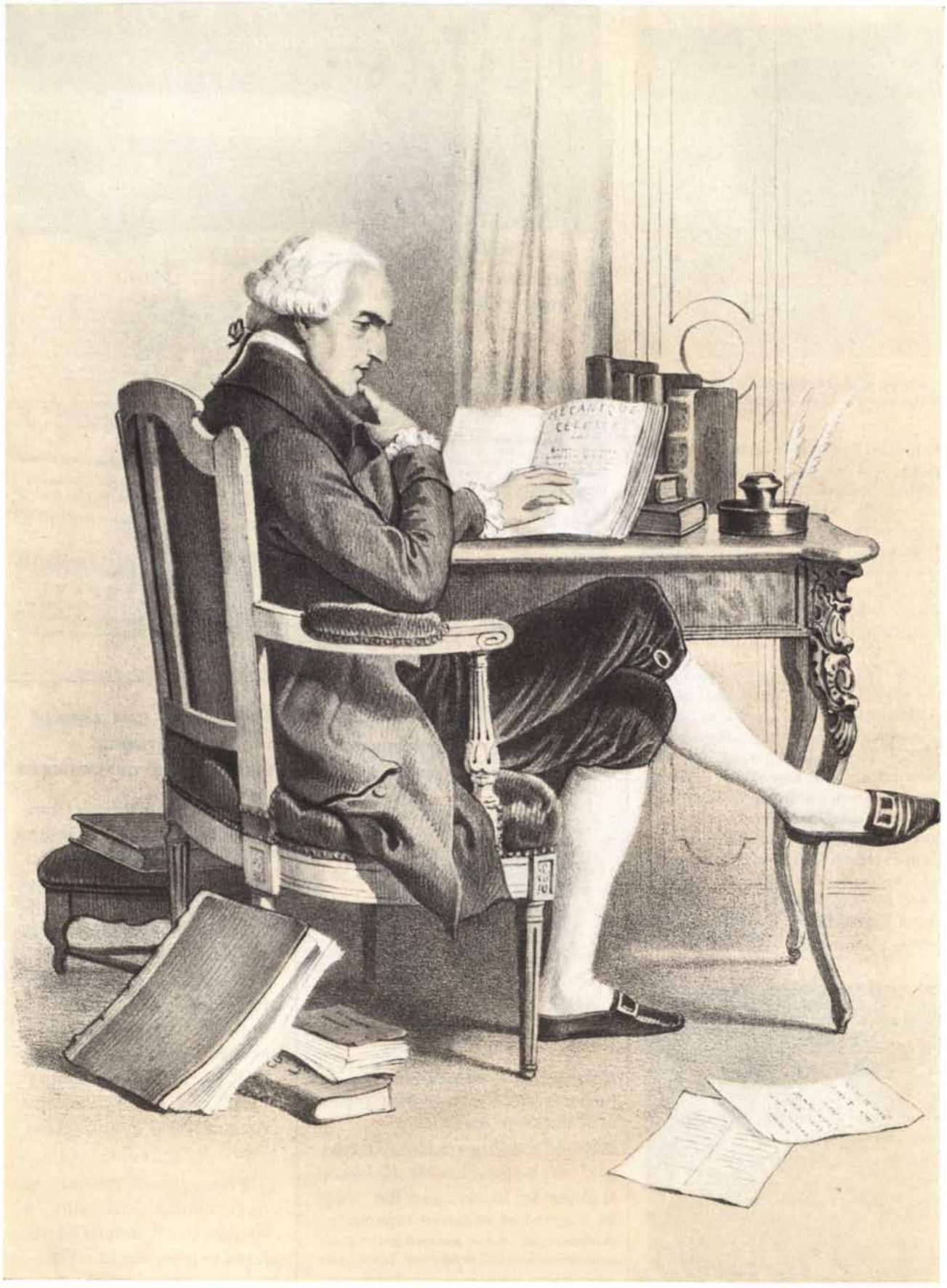
graph was made 25 seconds after the addition of the extract; the third, 10 seconds later.

ly specific; that is, cells of one species of sponge will not coalesce with those of another. Spiegel injected sponge cells into rabbits, which then formed antibodies to those cells. These antibodies, he discovered, interfered with the recombination of separated sponge cells of the same species when added to a suspension of such cells. The same results occurred when he used cells of amphibian embryos.

This type of investigation provides a lead toward understanding what makes cells and tissues adhere or fail to adhere to one another, how they influence one another during development and differentiation, and how they organize themselves into the organs of an animal. With the auto-antibody concept as a working hypothesis, biologists can now begin to search for the specific interacting, complementary pairs of substances which seem to constitute a most vital part of the machinery of living cells and tissues.



of serum from a rabbit which has been injected with other sponge cells; antibodies in serum prevent cells from clumping.



PIERRE SIMON DE LAPLACE was born in 1749 and died in 1827. This 19th-century lithograph shows him in the studied posture of reading a volume of his own *Mécanique céleste*, which systematized the gravitational studies of three generations of mathematicians.

Laplace

He did great work in mathematics, physics and astronomy but was not an entirely admirable man. While pursuing his scientific career he served three French governments: republic, empire and monarchy

by James R. Newman

Historians of science have rightly called the Marquis de Laplace the Newton of France. He earned the title for his immense work on celestial mechanics, which capped the labors of three generations of mathematical astronomers and produced a universal principle that has been applied to almost every field of physics. Biographers have found Laplace no less interesting—though less impressive—as a person than as a scientist. He was a man of curiously mixed qualities: ambitious but not unamiable, brilliant but not above stealing ideas shamelessly from others, supple enough to be by turns a republican and a royalist in the tempestuous time in which he lived—the era of the French Revolution.

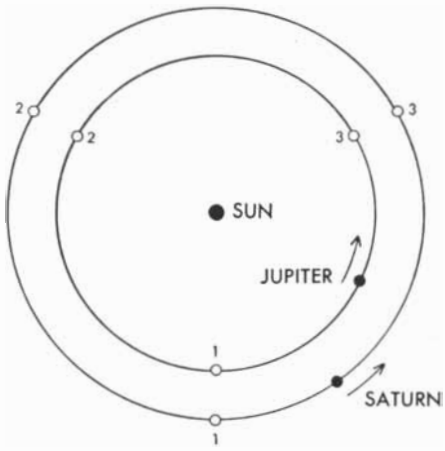
Pierre Simon de Laplace was born at Beaumont-en-Auge, a Normandy village in sight of the English Channel, on March 23, 1749. The facts of his life, of the earlier years especially, are both sparse and in dispute. Most of the original documents essential to an accurate account were burned in a fire which in 1925 destroyed the château of his great great grandson the Comte de Colbert-Laplace; others were lost during World War II in the bombardment of Caen. Many errors about Laplace's life have gained currency: that his father was a poor peasant, that he owed his education to the generosity of prosperous neighbors, that after he became famous he sought to conceal his "humble origins." Recent researches by the mathematician Sir Edmund Whittaker seem to show that whatever Laplace's reasons for reticence about his childhood, poverty of his parents was not among them. His father owned a small estate and was a syndic of the parish; his family belonged to the "good bourgeoisie of the land." One of Laplace's uncles was a surgeon, another a priest. The latter, a member of the teaching staff of the Benedictine Priory at Beaumont, where Laplace had his first schooling, is said to have awakened the boy's interest in mathematics. For a time it was thought that Laplace would follow his uncle's profession as a priest, but at the University of Caen, which he entered at the age of 16, he soon demonstrated his mathematical inclinations. He wrote a paper on the calculus of finite differences which was published in a journal edited by Joseph Louis Lagrange, the great mathematician, 13 years Laplace's senior, with whom he was later to collaborate.

When Laplace was 18, he set out for Paris. He carried enthusiastic letters of recommendation to Jean le Rond d'Alembert, the most prominent mathematician of France. D'Alembert ignored them; Laplace, not an easy fellow to put off, thereupon wrote him a letter on the general principles of mechanics which made so strong an impression that d'Alembert at once sent for the precocious young man and said: "Monsieur, as you see, I pay little enough attention to recommendations; you had no need of them. You made your worth known; that is enough for me; my support is your due." A short while later d'Alembert procured for him an appointment as professor of mathematics in the *Ecole Militaire* of Paris.

Laplace's rise was rapid and brilliant. He submitted to the Academy of Sciences one memoir after another applying his formidable mathematical capabilities to the outstanding questions of planetary theory. "We have never seen," said a spokesman for the usually imperturbable savants of the Academy, "a man so young present in so short a time so many important memoirs on such diverse and difficult problems."

One of the main problems Laplace ventured to attack was the perturbations of the planets. The anomalies of their motion had long been known; the English astronomer Edmund Halley had noted, for instance, that Jupiter and Saturn over the centuries alternately lagged behind and were accelerated ahead of their expected places in a peculiar kind of orbital horse race. The application of Newton's theory of gravitation to the behavior of the planets and their satellites entailed fearful difficulties. The famous three-body problem (how three bodies behave when attracting one another under the inverse square law) is not completely solved today; Laplace tackled the much more complex problem of all the planets cross-pulling on one another and on the sun.

Newton had feared that the planetary melee would in time derange the solar system and that God's help would be needed to restore order. Laplace decided to look elsewhere for reassurance. In a memoir described as "the most remarkable ever presented to a scientific society," he demonstrated that the perturbations of the planets were not cumulative but periodic. He then set out to establish a comprehensive rule concerning these oscillations and the inclination of the planetary orbits. This work bore on the fate of the entire solar system. If it could be shown that disturbances in the machinery were gradually overcome and the status quo restored—a kind of self-healing and self-preserving process



PERTURBATIONS of the planets were mathematically described by Laplace and Lagrange. When Jupiter and Saturn are in conjunction (on a line with the sun), one planet speeds up and the other slows down. Numbers indicate they are in conjunction three times in every five circuits of Jupiter.

analogous to the physiological principle which Walter Cannon has called homeostasis—the future of the cosmic machine, and of its accidental passenger, man, was reasonably secure. If, however, the disturbances tended to accumulate, and each oscillation simply paved the way for a wilder successor, catastrophe was the inevitable end. Laplace worked out a theoretical solution which seemed to fit observation, showing that the outcome would be happy, that the changes of the solar system merely "repeat themselves at regular intervals, and never exceed a certain moderate amount." The period itself is of course tremendously long; the oscillations are those of "a great pendulum of eternity which beats ages as our pendulums beat seconds."

Thus Laplace's theorems gave assurance of the reliability of the stellar clockwork of the universe; its peculiar wobbles and other irregularities were seen to be minor, self-correcting blemishes which in no sense threatened the revolutions of the engine as a whole. Indeed, Laplace regarded the anomalies as a boon to astronomers. He wrote in the *Mécanique céleste:* "The irregularities of the two planets appeared formerly to be inexplicable by the law of universal gravitation; they now form one of its most striking proofs. Such has been the fate of this brilliant discovery, that each difficulty which has arisen has become for it a new subject of triumph—a circumstance which is the surest characteristic of the true system of nature."

Two reservations about this work have to be noted. Laplace's solution did not completely prove the stability of the solar system. His solution would be valid for an idealized solar system undisturbed by tidal friction or other force; but the earth is now known, as it was not in Laplace's day, to be a non-rigid body subject to deformation by tidal friction, which thus acts as a brake on its motion. The effect is very small but acts always in one direction. Consequently we cannot conclude, as Laplace did, that nature arranged the operations of the celestial machine "for an eternal duration, upon the same principles as those which prevail so admirably upon the Earth, for the preservation of individuals and for the perpetuity of the species."

The second point concerns Laplace's failure to mention his indebtedness to Lagrange. Almost everything that Laplace accomplished in physical astronomy owes a debt to Lagrange's profound mathematical discoveries. It is impossible in many instances to separate their contributions. Lagrange was the greater mathematician; Laplace, for whom mathematics was only a means to an objective, was primarily a mathematical physicist and astronomer. Others have severely censured Laplace for his lack of acknowledgment of his collaborator's contributions, but Lagrange, obviously a saintly soul, did not; the two always remained on the best of terms.

Laplace's *Mécanique céleste* appeared in five immense volumes between 1799 and 1825. He described its scope as follows:

"We have given, in the first part of this work, the general principles of the equilibrium and motion of bodies. The application of these principles to the motions of the heavenly bodies has conducted us, by geometrical reasoning, without any hypothesis, to the law of universal attraction; the action of gravity, and the motion of projectiles, being particular cases of this law. We have then taken into consideration a system of bodies subjected to this great law of nature; and have obtained, by a singular analysis, the general expressions of their motions, of their figures, and of the oscillations of the fluids which cover them. From these expressions we have deduced all the known phenomena of the flow and ebb of the tide; the variations of the degrees, and of the force of gravity at the surface of the earth; the precession of the equinoxes; the libration of the moon; and the figure and rotation of Saturn's rings. We have also pointed out the cause why these rings remain permanently in the plane of the equator of Saturn. Moreover, we have deduced, from the same theory of gravity, the principal equations of the motions of the planets; particularly those of Jupiter and Saturn, whose great inequalities have a period of above 900 years."

Napoleon, on receiving a copy of the *Mécanique céleste*, protested to Laplace that in all its vast expanse God was not mentioned. The author replied that he had no need of this hypothesis. Napoleon, much amused, repeated the reply to Lagrange, who is said to have exclaimed: "Ah, but it is a beautiful hypothesis; it explains many things."

To mathematicians the work is especially memorable. The Irish mathematician William Rowan Hamilton is said to have begun his mathematical career by discovering a mistake in the *Mécanique céleste.* George Green, the English mathematician, derived from it a mathematical theory of electricity. Perhaps the greatest single contribution of the work was the famous Laplace equation:

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} = 0$$

Laplace's expression is a field equation, which is to say it can be used to describe what is happening at every instant of time at every point in a field produced by a gravitational mass, an electric charge, fluid flow and so on. Another way of saying this is that the equation deals with the value of a physical quantity, the potential, throughout a continuum. The potential function u, introduced in the first instance as a purely mathematical quantity, later acquired a physical meaning. The difference between the values of the potential function at two different points of a field measures the amount of work required to move a unit of matter from one of these points to the other; the rate of change of potential in any direction measures the force in that direction.

By giving u different meanings (*e.g.*, temperature, velocity potential and so on) the equation is found to have an enormous range of applications in the theories of electrostatics, gravitation, hydrodynamics, magnetism, sound, light, conduction of heat. In hydrodynamics, where u is the velocity potential (distance squared divided by time), the rate of change of potential is the measure of the velocity of the fluid. The equation applies to a fluid which is incompressible and indestructible; if as much fluid flows out of any tiny element of volume as flows in, the potential function satisfies Laplace's equation. A rough explanation of why this equation serves as an almost universal solvent of physical problems is that it describes a characteristic economy of natural behavior—"a general tendency

toward uniformity so that local inequalities tend to be smoothed out." Thus a metal rod heated at one end tends to become of uniform temperature throughout; a solute in a liquid tends to distribute itself evenly.

The *Mécanique céleste* is a book whose difficulties are proportional to its bulk. Laplace made no concession to the reader. He bridged great gaps in the argument with the infuriating phrase "it is easy to see." The U. S. mathematician and astronomer Nathaniel Bowditch, who translated four of the volumes into English, said he never came across this expression "without feeling sure that I have hours of hard work before me to fill up the chasm." Laplace himself, when required to reconstruct some of his reasoning, confessed he found it not at all "*aisé à voir*" how his conclusions had been reached. Nor is it a modest or entirely honorable writing. "Theorems and formulae," wrote Agnes Mary Clerke, the noted historian of astronomy, "are appropriated wholesale without acknowledgment, and a production which may be described as the organized result of a century of patient toil presents itself to the world as the offspring of a single brain." The biographer Eric Temple Bell has remarked that it was Laplace's practice to "steal outrageously, right and left, wherever he could lay his hands on anything of his contemporaries and predecessors which he could use."

For those unable to follow the formidable abstractions of the *Mécanique* Laplace wrote in 1796 the *Exposition du système du monde*, one of the most charming and lucid popular treatises on astronomy ever published. In this masterpiece Laplace put forward his famous nebular hypothesis (which had been anticipated by Immanuel Kant in 1755). Its gist is that the solar system evolved from a rotating mass of gas, which condensed to form the sun and later threw off a series of gaseous rings that became the planets. While still in the gaseous state the planets threw off rings which became satellites. The hypothesis has had its ups and downs since Kant and Laplace advanced it. In Laplace's theory revolution in a retrograde direction by a member of the solar system was impossible; yet before Laplace died Sir William Herschel found that the satellites of Uranus misbehaved in this way, and others have since been discovered. Yet the theory was an intellectual landmark, and much of its basic reasoning is still accepted by some cosmologists as valid for astronomical aggregates larger than the solar system.

Another subject upon which Laplace bestowed his attention, both as a mathematician and as a popularizer, is the theory of probability. His comprehensive treatise *Théorie analytique des probabilités* described a useful calculus for assigning a "degree of rational" belief to propositions about chance events. Its framework was the science of permutations and combinations, which might be called the mathematics of possibility.

The theory of probability, said Laplace, is at bottom nothing more than common sense reduced to calculation. But his treatise seemed to indicate that the arithmetic of common sense is even more intricate than that of the planets. No less a mathematician than Augustus De Morgan described it as "by very much the most difficult mathematical work we have ever met with," exceeding in complexity the *Mécanique céleste*.

Laplace's contributions to probability are perhaps unequaled by any other single investigator; nevertheless the *Théorie analytique*, like the *Mécanique*, failed to acknowledge the labors of other mathematicians, on which many of its conclusions depended. De Morgan said of Laplace: "There is enough originating from himself to make any reader wonder that one who could so well afford to state what he had taken from others, should have set an example so dangerous to his own claims."

In a companion work, the *Essai philosophique sur les probabilités*, presenting a nontechnical introduction to the laws of chance, Laplace wrote a passage which is regarded as the most perfect statement of the deterministic interpretation of the universe, a symbol of that happy and confident age which supposed that the past could be described and the future predicted from a single snapshot of the present:

"We ought then to regard the present state of the universe as the effect of its anterior state and as the cause of the one which is to follow. Given for one instant an intelligence which could comprehend all the forces by which nature is animated and the respective situation of the beings who compose it—an intelligence sufficiently vast to submit these data to analysis—it would embrace in the same formula the movements of the greatest bodies of the universe and those of the lightest atom; for it, nothing would be uncertain and the future, as the past, would be present to its eyes. The human mind offers, in the perfection which it has been able to give to astronomy, a feeble idea of this intelligence. Its discoveries in mechanics and geometry, added to that of universal gravity, have

enabled it to comprehend in the same analytical expressions the past and future states of the system of the world. Applying the same method to some other objects of its knowledge, it has succeeded in referring to general laws observed phenomena and in foreseeing those which given circumstances ought to produce. All these efforts in the search for truth tend to lead it back continually to the vast intelligence which we have just mentioned, but from which it will always remain infinitely removed. This tendency, peculiar to the human race, is that which renders it superior to animals; and their progress in this respect distinguishes nations and ages and constitutes their true glory."

Together with the great chemist Antoine Lavoisier, Laplace engaged in experiments to determine the specific heats of a number of substances. They designed the instrument known as Laplace's ice calorimeter, which measures heat by the amount of ice melted, a method employed earlier by the Scottish chemist Joseph Black and the German Johann Karl Wilke.

Laplace prospered financially and politically; Lavoisier died on the guillotine. In 1784 Laplace was appointed "examiner to the royal artillery," a lucrative post and one in which he had the good fortune to examine a promising 16-year-old candidate named Napoleon Bonaparte. The relationship was to blossom forth 20 years later, much to Laplace's advantage. With Lagrange, Laplace taught mathematics at the *Ecole Normale*, became a member and then president of the Bureau of Longitudes, aided in the introduction of the decimal system and suggested, in keeping with the reform spirit of the Revolution, the adoption of a new calendar based on certain astronomical calculations.

There is some reason to believe that for a brief period during the Revolution Laplace fell under suspicion; he was removed from the commission of weights and measures. But he managed not only to hold on to his head but to win new honors. He had a knack for riding the waves of his turbulent era. Under the Republic he was an ardent Republican and declared his "inextinguishable hatred to royalty." The day following the 18th Brumaire (November 9, 1799), when Napoleon seized power, he shed his Republicanism and formed an ardent attachment for the first consul, whom he had helped earlier to form a Commission for Egypt. Almost immediately Napoleon rewarded Laplace with the portfolio of the Interior. The evening of his appointment the new minister demanded a pension of 2,000 francs for the widow of the noted scholar Jean Bailly, executed during the Terror, and early the next morning Madame Laplace herself brought the first half-year's income to "this victim of the passions of the epoch." It was a "noble beginning," as Laplace's protégé François Arago wrote, but it is hard to discover any other noble accomplishment gracing Laplace's ministerial career. His tenure of office was brief—six weeks. Napoleon wrote tartly of Laplace's shortcomings in his St. Helena memoirs: "He was a worse than mediocre administrator who searched everywhere for subtleties, and brought into the affairs of government the spirit of the infinitely small." But to soothe the hurt of his dismissal the deposed minister was given a seat in the Senate and in 1803 became its Chancellor.

Historians have amused themselves describing Laplace's skill in running with the hare and hunting with the hounds. The neatest evidence appears in his introductions to successive editions of his books. He inscribed the first edition of the *Système du monde* in 1796 to the Council of Five Hundred, and in 1802 prefixed the third volume of the *Mécanique céleste* with a worshipful paean to Napoleon, who had dispersed the Council. Laplace dedicated the 1812 edition of the *Théorie analytique des probabilités* to "Napoleon the Great"; in the 1814 edition he suppressed this dedication and wrote "that the fall of empires which aspired to universal dominion could be predicted with very high probability by one versed in the calculus of chances." Napoleon had made Laplace a count; this gave him the opportunity to join in the 1814 decree of forfeiture banishing the man who had made him a count. When the Bourbons returned, Laplace was one of the first to fall at their feet; for this genuflection he received a marquisate.

Laplace was not an evil or a malicious man. He gave a hand up to many younger scientists. At his country home in Arcueil he surrounded himself with "adopted children of his thought": Arago, an astronomer and physicist; the physicist Jean Biot, noted for his investigations of the polarization of light; Baron Alexander von Humboldt, the celebrated German naturalist and traveler; Joseph Gay-Lussac, the great chemist and physicist; Siméon Poisson, the brilliant mathematician. Biot related that after he had read a paper on the theory of equations, Laplace took him aside and showed him "under a strict pledge of secrecy papers

vellow with age in which he had long before obtained the same results." Having soothed his ego, Laplace told the young man to say nothing about the earlier work and to publish his own.

The almost universal admiration for Laplace's scientific genius did not mitigate the widespread distrust inspired by his political adaptability. The more tolerantly cynical of his contemporaries referred to his "suppleness." The stock appraisal is to compare him to the Vicar of Bray. The Vicar, an accommodating man who was twice a Papist and twice a Protestant, is said to have defended the charge of being a time-server by replying: "Not so, neither, for if I changed my religions, I am sure I kept true to my principle, which is to live and die the Vicar of Bray." Laplace could have made similar answer.

About his family life and personal habits there is a strange lack of information. Laplace's marriage with Charlotte de Courty de Romanges, contracted in 1788, was apparently a happy one. They had a daughter and a son, Emile, who rose to the rank of general in the artillery. In later years Laplace passed much of his time at Arcueil, where he had a house next to the chemist Count de Berthollet. There in his study, where the portrait of Racine, his favorite author, hung opposite that of Newton, he pursued his studies with "unabated ardor" and received "distinguished visitors from all parts of the world." He died on March 5, 1827, a few days before his 78th birthday. Illustrious men are required to say deathless things on their deathbeds. Laplace is said to have departed after expressing the reasonable opinion, "What we know is very slight; what we don't know is immense." De Morgan, observing that "this looks like a parody on Newton's pebbles," claimed to have learned on close authority that Laplace's very last words were: "Man follows only phantoms."

ASTRONOMICAL DECORATION is from the title page of Laplace's *Théorie du mouvement et de la figure elliptique des planètes.*

Early Man in the Arctic

The similarity of stone tools found at many locations around the North Pole suggests that a well-defined culture existed in the Arctic long before man migrated southward in America

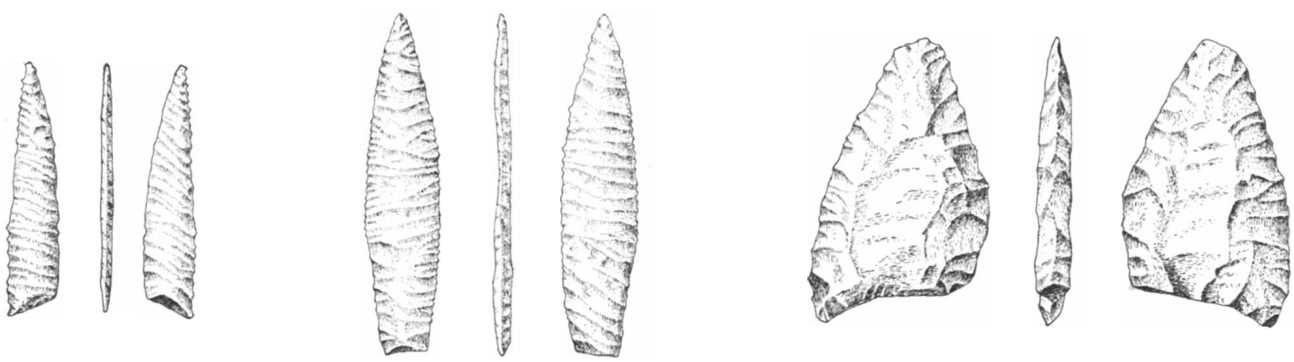
by J. L. Giddings, Jr.

On a windswept trail in the far north near Hudson Bay there was discovered last summer a deposit of prehistoric hunters' flints which has radically disturbed long-accepted notions about the original peopling of America. Archaeologists had built up, from the little evidence they had, what seemed a plausible picture: About 10,000 to 15,000 years ago roving bands of hunters from Asia, either following herds of animals or seeking a virgin "promised land," crossed from Asia to Alaska over a Bering Strait land bridge ["How Man Came to North America," by Ralph Solecki; SCIENTIFIC AMERICAN, January, 1951]. Most of the immigrants, supposedly a simple, comparatively unresourceful people, then pushed south down the North American continent to less rigorous climates, while a few tribes remained in the Arctic, surviving as the Eskimos of today. What is disturbing about the new find is that it forms a connecting link in an unexpected chain of early human habitation stretching around the Arctic Circle all the way from northern Europe across Asia and North America—a chain of able, resourceful peoples with a relatively advanced hunters' culture!

The idea of a Bering Strait gateway for Americans gained credence long before archaeology began in the far north. Some natural historians of the early 1800s thought the Indian mound builders of the Mississippi basin could be traced back along this trail to the areas of stone monuments in the Middle East and Europe. Later the ethnologists postulated the migrations over a "land bridge" between the continents and along valleys between Alaskan and Canadian glaciers. Speculations on this score, and on the relationship of early migrants to Eskimos, could be made without fear of contradiction because discoveries of very old artifacts were so few as to lie comfortably in almost any theoretical bed. The Folsom flints unearthed in our western deserts and plains appeared to confirm the picture of moving bands of hunters.

But during the last few years the new chain of sites found in the far north has raised puzzling questions. The sites around the Arctic Circle seem more closely related to one another culturally than do the sites along the trail from north to south. It is disturbing to students of "migrating" New World men to find that not only Eskimo culture but earlier cultures within the same area may have been mainly Arctic phenomena. If the far north has for thousands of years supported cultures well fitted to the region, how shall we explain the original peopling of the Americas?

The beginning of the dilemma goes back to discoveries on the campus of the University of Alaska near Fairbanks in the early 1930s. A student watching the freshman bonfire on the brow of College Hill one autumn evening scuffed up a flint point which led to a series of



FLINTS used by Stone Age hunters were found at Cape Denbigh, Alaska (*see map on page 84*). **Six of the finely worked specimens are shown in three views at slightly less than actual size. The side blade** (*far left*) **was designed to be fitted into an arrow along the**

excavations by the anthropology department. These brought to light a stone industry which the experienced archaeologist N. C. Nelson found similar to artifacts unearthed in Mesolithic sites in the Gobi Desert of Mongolia. The most characteristic feature of this work was a certain peculiar type of parallel-edged "microblade"—a thin sliver chipped delicately from a prepared flint core [*see photograph on page 88*]. The microblades involve a precise technique which can hardly have been learned independently in different places by chance.

For a time the Alaska campus site stood in an anomalous place—an almost unwelcome proof of connections between Asia and America because it held neither the earliest nor the later forms of the flints of the western plains. But it soon became part of a developing new picture in the Arctic. Similar microblade industries were discovered in the Brooks Range in northern Alaska, in early stratigraphic levels at Kluane Lake in Canada's Yukon Territory, and at Pointed Mountain and elsewhere in the Mackenzie River basin. The microblade and core, in other associations, are being recognized at various sites across northern Siberia and throughout the American Arctic.

In 1948 we made a field trip to Cape Denbigh, on the northern shore of Bering Sea, with the usual objective of digging under an Eskimo midden in the hope of finding an older culture. At a coastal spot known to the Eskimos as Iyatayet, on top of an ancient 40-foot terrace, we slowly exposed the floor and lower walls of a pit house several centuries old. It was a house of the "neo-Eskimo" period, and its culture was so nearly like that of the people now living in the area that our native helpers had no trouble in explaining details of use in the articles and structures uncovered.

Beneath the splinters of old flooring a test cut at the back of the house unexpectedly revealed that the dwelling had been originally set in soil containing the cultural deposits of some earlier people. Bits of well-fired pottery, thin side blades and arrow points of basalt and flintlike gray chert marked this as a deposit of the "paleo-Eskimo" culture, previously discovered only at a site at Point Hope far to the north.

The real surprise lay still deeper. On troweling through a sterile layer below the early Eskimo, we came to a dense clay, on the top of which lay quantities of small chips of chert and obsidian—and microblades in profusion! The artifacts in this level, now known as the Denbigh flint complex, continued to amaze us during the field seasons of 1949, 1950 and 1952. The microblades are like those of the University site, but there the resemblance ends. There are many tiny blades carefully shaped by diagonal flaking into thin and delicate side and end blades, the precision of which appears to be without equal elsewhere in the world. Other small blades were made into various tools by simply retouching parts of their edges.

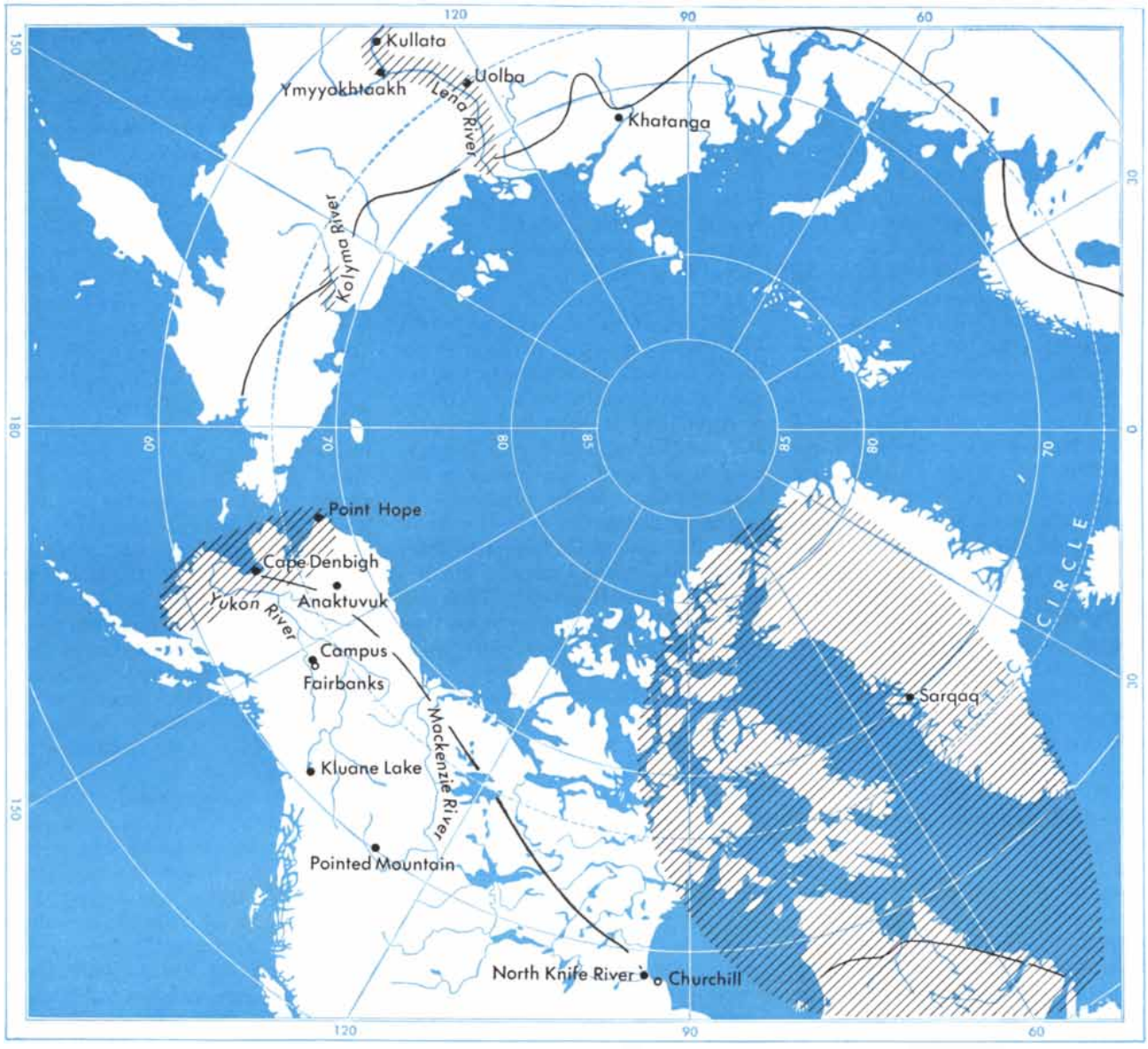
Of the few large blades found in the complex, nearly all resemble ancient weapons unearthed in the plains and southwest areas of the U. S., where they are linked with early Americans' hunting of now extinct animals. They include a fluted point in the Folsom tradition and about a dozen fragments of the long, diagonally-flaked points known as the "Yuma oblique." With this distant tie to early Americans as incentive, I looked farther afield for comparisons in Old World literature, and to my surprise I found the Denbigh flint complex closely related to artifacts in the caves of Europe and the forests of Siberia.

The least expected find in the Denbigh flint complex was a number of forms of the burin—a grooving instrument which we deduced was used for sectioning antler, ivory and other hard organic material. At the time of its discovery at Cape Denbigh, this implement had not previously been recognized in America, though it was well known as a basic tool of the Upper Paleolithic and the Mesolithic periods in European prehistory. The Denbigh burin is a thin implement with teeth formed by chipping out one or more needle-like slivers. The slivers themselves also were used, probably as hafted engraving tools. Enlargement of one of these slivers, less than an inch in length, shows that its tip is a chisel.

As to the geological background of the Iyatayet site, D. M. Hopkins of the U. S. Geological Survey has joined with me to show that the deeper soil layers have been subject to movements and soil-forming processes no longer active. These layers record a sequence of climatic changes similar to known sequences in other parts of Alaska. Converging lines of evidence lead us to believe that the earliest dwellers at Iyatayet lived during a warm period more than 8,000 years ago. Unfortunately it has been impossible to date the level accurately by the radiocarbon method. The paleo-Eskimo level at this site, according to dating of its charcoal, is about 2,000 to 1,500 years old, and the neo-Eskimo occupation seems to have lasted from about 1200 to 1600 A.D.

While the story of Cape Denbigh and its Old World connections slowly unfolded, a colleague exposed surprisingly

shaft behind an end point (*second from left*). The fluted point (*third*) resembles those of the Folsom type found in the U. S. Southwest, while the large point (*fourth*) is of the type termed "Yuma oblique." Burins (*fifth and sixth*) were used as grooving tools.

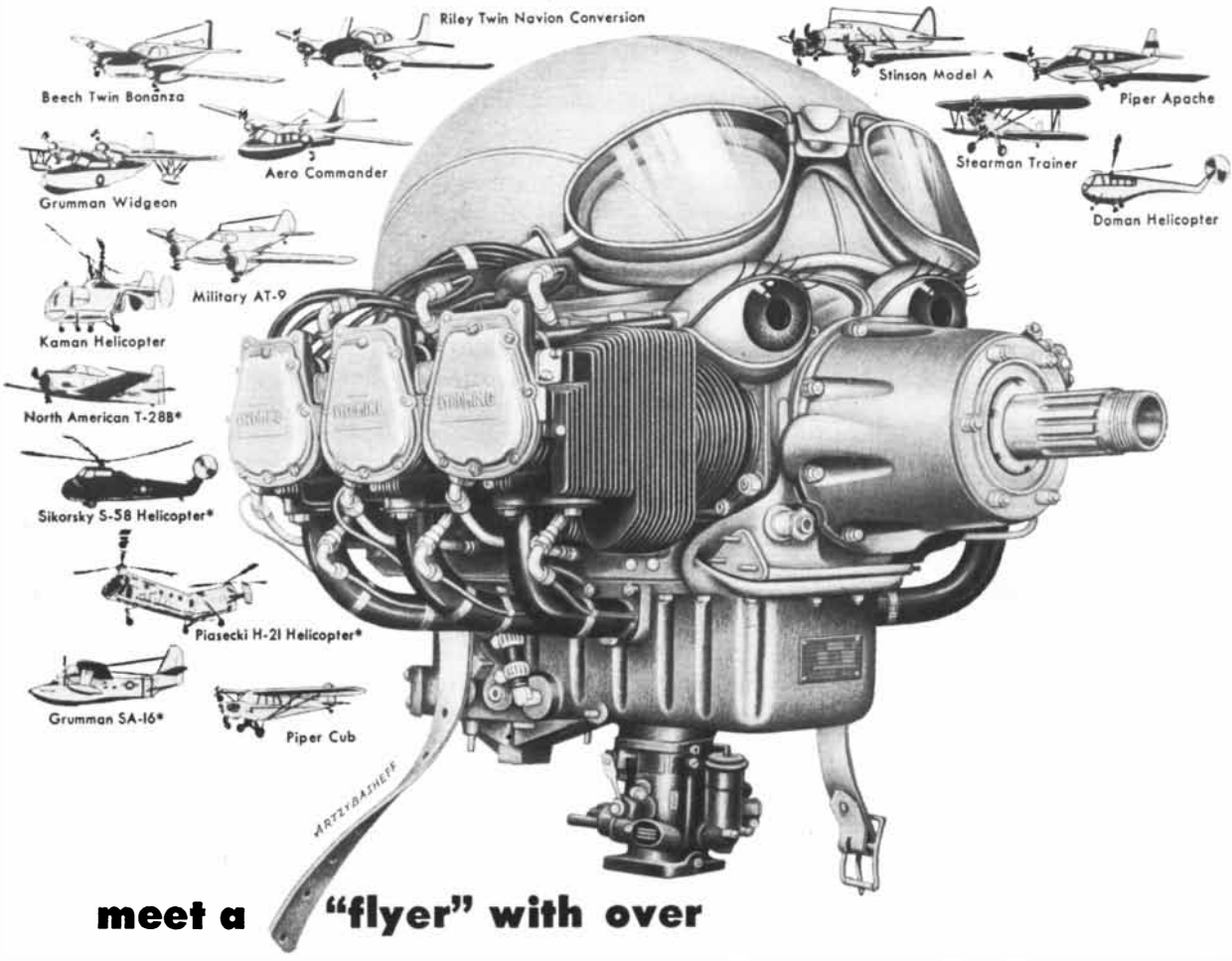


PRINCIPAL SITES at which tools were found are indicated by the black dots on this polar projection of the Arctic. The hatching at the top indicates the main region of such finds in Siberia. The hatching at the left outlines the known area of the paleo-Eskimo culture. The hatching at right shows the general extent of the Dorset culture. The black line indicates the northern limit of trees.

similar cultural veins in neighboring areas. In 1949 Helge Larsen, of the National Museum of Denmark, discovered in mountain caves on the north side of Seward Peninsula a stratigraphic sequence in which microblades lay at the bottom. The following year his party again attacked the caves and came up with an interesting sequence. Near the bottom of the caves they found, along with material like the Denbigh flint complex, some unique artifacts which have not yet been described in print. Among them are slender antler shafts with side grooves into which microblades fit—a characteristic of certain Mesolithic sites of northern Europe and Asia. We cannot yet say whether these finds are older or younger than the Denbigh flint complex.

As microblades have turned up at other sites along the Arctic Circle, the idea has grown upon me that the people of the early flint complexes flourished on the forest edge—near the northern limit of spruce. Denbigh and some of the other sites are at the tree line today; there is evidence that forests extended, within the last few thousand years, even farther north than they do now. A hunting group living near the forest edge can retreat to it for tent poles and fuel, for moose and bear and for shelter from wind and cold. The barren lands beyond the forests are the highroads of caribou, as they must have been in earlier times for horses and bison, and it is here that hunters find it easiest to outwit large numbers of animals at the times of their annual crossings. Those who live at the tree line are doubly insured.

Last July I went to a settlement on the tree line far east of Alaska—the village of Churchill on the western shore of Hudson Bay. My main mission had to do with studying climate in tree rings, but I talked with the inhabitants about flint chips and arrowheads, in hopes of evoking the memory of some half-forgotten site. Just before leaving for a trip north into the barren lands inhabited by Caribou Eskimos, I had the good fortune to be shown a handful of flints which a



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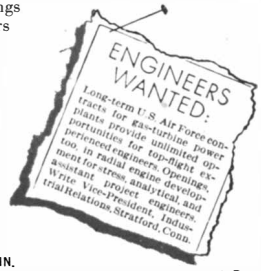

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*Wright-Cyclone engine, built by Lycoming under license from Curtiss-Wright Corporation, Wright Aeronautical Division.

Chipewyan Indian had shortly before given to a prominent resident of Churchill. In this collection of a dozen delicate objects of white chalcedony and agate were end blades, fragments of side blades and burins!

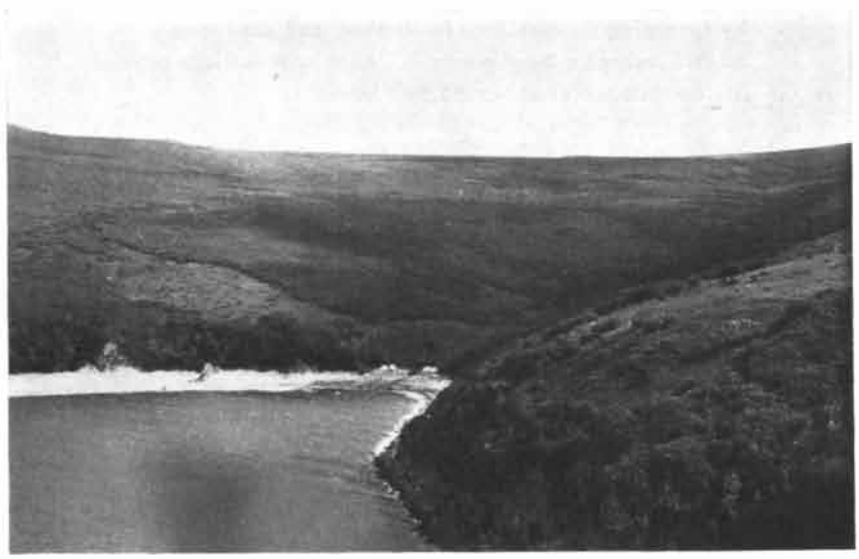
I thought at first these remains might belong to the so-called Dorset culture—an early Eskimo people who occupied Greenland and eastern Canada more than a thousand years ago. But under scrutiny the objects looked unlike those of the Dorset culture. In August the man who had found the flints and an Indian companion guided me to the site. It was some distance up the swift North Knife River, a stream that flows into Hudson Bay northwest of Churchill. We traveled by canoe about 25 miles up the river and then hiked a mile or more upland. The site lay on a strip of windblown sand and moss-covered ground between an old terrace and a long, shallow lake. In blown-out pits, where the milling of caribou had broken the sod and exposed the underlying sand to the wind, we found hundreds of chips of flinty material left by some early people, and a number of whole or broken artifacts. My companions explained that they had often hunted caribou at this place, but they professed to have no knowledge, legendary or otherwise, of the people who had left the flints.

The exciting fact soon emerged that this was indeed a site of burins and side blades, in addition to many of the sharpening spalls of burins, end blades and various scrapers. In all of the artifacts and raw chips, however, we found not a single microblade. This could not be Dorset culture. I remembered that a Danish archaeologist, Jorgen Meldgaard, had recently discovered at Sarqaq in Greenland side blades and burins which he thought were not Dorset either.

When I returned to Philadelphia from Hudson Bay, I wrote at once to Larsen in Copenhagen, telling him of my discovery. Again coincidence had worked! He wrote that his party had just returned from Disko Bay on the Greenland west coast. They had found a three-stratum site, containing the remains of neo-Eskimos on top, artifacts of the Dorset culture below, and at the bottom, beneath sterile soil, a layer containing only objects like those at Sarqaq. The Sarqaq and the Knife River finds, though mostly unlike in their precise form and style of workmanship, are remarkably alike in their broader types and frequency. And so the picture continues to emerge.

The clues that we have so far are only bits and patches, but two possible alternate patterns are beginning to take form. We may reason, on one hand, that the sterile layers between the deposits of artifacts represent periods when the population had moved away from the whole region, and that the successive occupations were by new migrations. An extreme proponent of the migration theory might say that the Denbigh flint people came from Asia and then journeyed south, that much later the paleo-Eskimos came out of Asia and settled for a time in Alaska before moving to the eastern Arctic, and that finally the Eskimos of today arrived and remained.

In the opposite view, we can assume that the village sites that have been unearthed were merely abandoned for



CAPE DENBIGH SITE at which artifacts were found is photographed from the air. In the foreground is an arm of the Bering Sea. The spot is called Iyatayet by the Eskimos.

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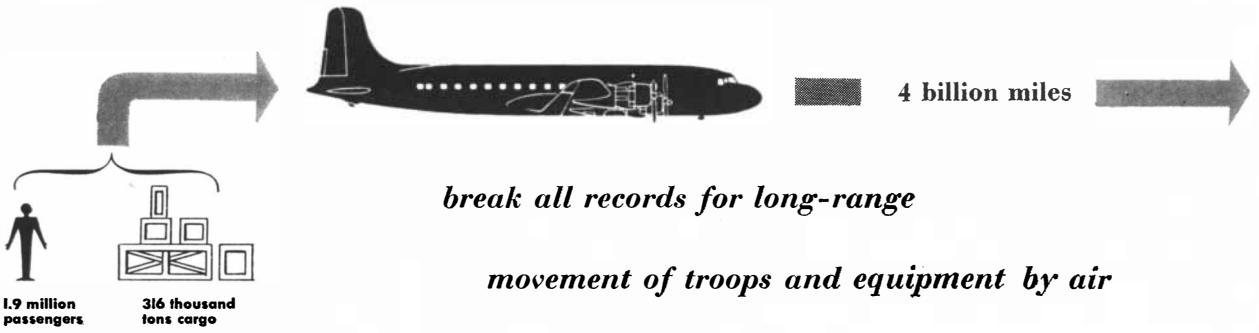

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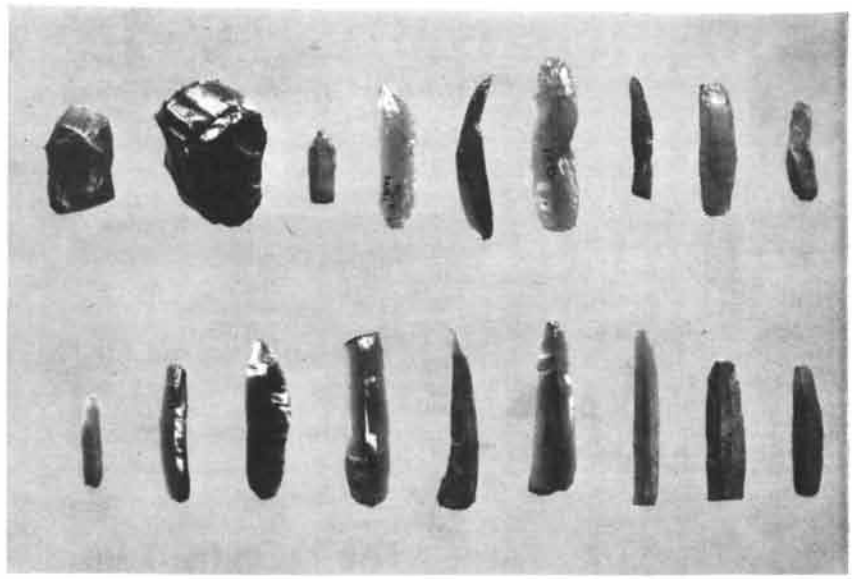

MICROBLADES were found in profusion at the Cape Denbigh site. They were struck from a larger stone, or core, with one blow. The large black stone at the upper left is such a core.

other habitations nearby. A hunting people move about in search of game but seldom venture far from the familiar hills, streams and meeting places that they know as home. We may suppose that our discoveries of flint collections are rare glimpses of a hunting people at rest. I am inclined to this second view. The movement of a northern hunting family in the course of a year from its spring hunting grounds to its summer fishing banks to its autumn caribou crossings does not lessen its feelings of attachment to any of these places. "Home" for such people is often the area within which customary social and economic contacts are made, rather than any fixed village.

I am most skeptical of the idea that people from Asia picked up and deliberately undertook a long migration. Rather, I favor the theory that a very sparse Arctic population slowly spread over the belt of northern climate, neither pursuing nor evading pursuit, but simply existing and adjusting at random to the environment, the sons sometimes hunting beyond the range of their fathers but never really leaving home. Once established in the Bering Strait region, a population can hardly ever have drifted away completely, for the area had the resources of the predictable sea plus those of the rivers and nearby forests.

The flint work of the Denbigh flint complex, the oldest cultural horizon yet identified in the Bering Strait region, is not only unique but possibly the world's most sophisticated. It shows no signs of having been brought there *in toto* from elsewhere. The Bering Strait region was already a "culture center" at the time of deposit of the Denbigh flint layer. Its emanations were being felt both to the east and to the west. Since the culture at Bering Strait was more complicated than those nearby, there cannot have been a strictly one-way diffusion of ideas to either continent. People at Bering Strait could have passed along ideas received from either direction, but they would also have originated and disseminated ideas of their own.

One is struck by the fact that most of the early flint techniques were distributed primarily in a broad band centering at the Arctic Circle; they seldom strayed south. Proponents of a "circumpolar" culture have shown repeatedly that a high degree of identity exists in specific forms of objects across all of the Arctic—including hair combs, knife blades, skin boats, side blades and many other examples. To these may be added, for very early times and with emphasis, microblades and burins.

Shall we, then, regard the Arctic as a broad region where thin populations long ago spread themselves into all of the parts where meat was available—enjoying slowly changing cultures that have surmounted and actually taken advantage of the environment? Such a view leaves little room for migrating hordes. It suggests instead that America was first settled by people slowly filtering down from the Arctic population, reassorting their genes variously in the New World down through the millennia and drawing at first for their changing culture on circumpolar ideas.

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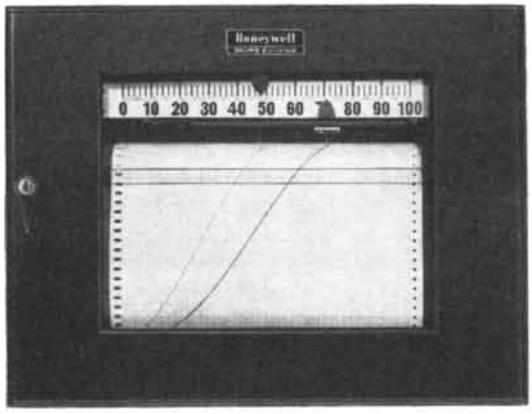

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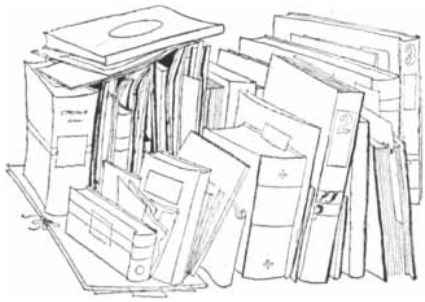


BOOKS

What is the condition of a Pacific island a decade after it was devastated by war?

by James R. Newman

SAIPAN, by Alexander Spoehr. Chicago Natural History Museum ($5.00).

About 150 miles north-northeast of Guam, in the Marianas group of Micronesia, lies the small, handsome tropical island of Saipan. Only about 12 miles long and five miles across at its widest point, it is shaped remarkably like a rhinoceros, with its horned snout pointing north. The island is bordered by white-coral sand beaches, barrier reefs and occasional stretches of steep cliffs. Of its permanent population of some 5,000 persons, four fifths are an oceanic people, the Chamorros, whose culture shows a strong Spanish influence; the other fifth are descendants of an ethnically different people who came to the island in 1815 from a typhoon-devastated area of the Caroline Islands.

Saipan has had the misfortune of being for three centuries a pawn in the game of colonial expansion. It was proclaimed Spanish territory in 1565 by the conqueror of the Philippines, López de Legazpi, and was settled by Spanish administrators in 1668. After more than 200 years of Spanish rule, the Marianas were gobbled up by more vigorous powers. Guam was seized by the U. S. in the Spanish-American War, and a year later Germany bought from Spain Saipan and the other Marianas Islands north of Guam. In October, 1914, the Japanese Navy took over these islands while the Reich had its hands full in Europe.

In 1944, after one of the bitterest, most destructive battles of the late war, Saipan came under the dominion of the U. S.; it is at present a ward of the Navy. Spoehr's book is an account of the island's past and of its present condition; he has subtitled it "The Ethnology of a War-Devastated Island."

The people of Saipan have enjoyed, if that is the right word, an unusually lively history. They have sampled the benefits of Spanish culture, German hygiene, Japanese efficiency and American bulldozers; they have experienced the protection of no fewer than four different powers in 50 years; they have seen their little island used as a fortress, a great military encampment and a bloody battleground. Like most innocent bystanders since the beginning of time, they have had their heads bashed in without provocation or compensation.

Today Saipan is "a strange and incongruous mixture of natural beauty and the ugly, abandoned remains of war." The ruins of its main town lie buried beneath several feet of crushed limestone on which huge warehouses were built—warehouses now empty and rotting. The countryside is dotted with wrecked and burned-out farmhouses. The landscape is a scene of rusty Quonset huts, deserted airstrips and telephone exchanges, junked equipment and machines, the "sagging remains" of officers' clubs, hamburger stands, Red Cross libraries and chapels. The people are confused, unable either to resume their prewar occupations or as yet to find new modes of subsistence. The villages are gone, the fields overgrown, the communal organizations shattered—"there are no well-ordered relationships between man and nature." Aliens have trampled on Saipan with iron boots, and it will be a long time before the inhabitants can repair the damage and build a stable social and economic life; perhaps, even with outside help, the task will prove impossible.

Alexander Spoehr is a well-known anthropologist, formerly curator of oceanic ethnology at the Chicago Natural History Museum and now director of the Bernice P. Bishop Museum in Honolulu. His excellent study of Saipan is based on observations during a year's archaeological and ethnological expedition there in 1949-1950. His analysis is sympathetic, but also clinically objective and admirably free of sentimentality. It is a sobering, deeply disturbing story, giving fresh and compelling meaning to John Donne's famous though now much overworked phrase about man's indifference to man.

When the Spaniards sent their first mission to the Marianas in 1668, their purpose was to convert the inhabitants to Christianity and to subjugate them politically. Both programs were successful. The Chamorros became and have remained devout Catholics; they exchanged Western beliefs for their own, adopted new agricultural practices and attended Spanish schools. The Chamorros have always been compliant respecters of authority; one of their well-educated spokesmen wrote in 1929 "that it is Chamorro nature to believe everything without questioning."

The Spaniards centralized their administration and control on Guam and gradually stripped the other Marianas Islands of their population. By the end of the 17th century Saipan was deserted. European diseases decimated the native population; from at least 50,000 when the Spaniards arrived, the number of full-blooded Chamorros had dropped to 1,318 by 1786. Then the population curve started to climb, as Filipinos came to Guam and intermarried with the natives. Today the Chamorros are a racially mixed group with a correspondingly mixed but well-defined culture.

In 1815 the Spaniards allowed an outside group who had been forced to abandon the Caroline Islands to resettle on Saipan. The Chamorros then began to trickle back to the island. Having, so to speak, been to the big city, they looked down on the more rustic Carolinians, whose women grew taros, yams and sweet potatoes, and whose men built canoes, traded and fished. The two groups remained socially and culturally distinct, but relations between them were amicable. Nineteenth-century observers described the Carolinians as simple and docile people who were quite prepared to acknowledge the superiority of the Chamorros and yield to their authority—without paying them the final tribute of imitation.

When the Germans took over Saipan in 1899, it was a peaceful island—sleepy, comfortable, economically self-sufficient. Its people were "few in numbers and of simple wants." They grew a wide variety of crops, including tobacco. Their principal town, Garapan, was a place of

broad streets with a masonry church and a fine residence for the *alcalde* and one for the missionary.

The German officials and visitors, of whom there was never more than a handful, made a distinct contribution to the island's general welfare. They introduced public health measures and vaccinated the population against smallpox, long a scourge of the island. The famous bacteriologist Robert Koch visited Saipan, and thereafter yaws ceased to be diagnosed as leprosy or confused with syphilis. The Germans set up schools and taught the inhabitants German, arithmetic, Biblical history, geography, music and calisthenics. (Many middle-aged persons on Saipan still speak German and can sing "*Ich weiss nicht was soll es bedeuten.*") They sent promising young men away to learn carpentry, blacksmithing and shoemaking; one became a schoolteacher "and a remarkably well-educated man, with a full command of at least five languages." The Germans also improved the efficiency of the administrative system, established a police force, instituted minor ordinances and began the keeping of vital statistics. They started a homesteading plan, encouraging copra planting and subsistence agriculture, which attracted Chamorros away from the U. S.-administered island of Guam. The migration was accelerated when the U. S. authorities on Guam began to urge the Carolinians there to adopt Western clothing and customs; the entire colony promptly departed for Saipan, where the officials were not unstrung by the sight of loin cloths and naked bosoms.

The Chamorros, with what one German scholar described as "their unmistakable urge toward progress," were receptive to the German precepts of work, thrift, order, punctuality and obedience. Some began to amass landholdings through the homestead plan; others started a soap factory; still others developed craft skills or became schoolteachers. The Carolinians, less impressed by Western ideas, continued to take things easy. Both groups now speak of the German period on Saipan as the "good old days." Allowing for the common tendency to gild the past, it remains true that the island's resources were abundant, life was leisurely, order and stability prevailed and "there was a modest outlet for those who wished to strive for wealth and knowledge."

But those happy days were numbered. In 1914 the new Japanese masters began a radical economic and cultural transformation of Saipan. To exploit it for the maximum contribution to the empire, they brought to the island thousands of Japanese (mostly Okinawan farmers and fishermen), established a sugar cane industry, began to grow coffee, cassava and pineapples, and instituted commercial fishing. They built a large sugar mill and a town for the millworkers, installed a narrow-gauge railroad to haul the cane, cleared almost all the arable land and leased it to sugar-raising tenant farmers, made extensive harbor improvements. Garapan became a predominantly Japa-

Garapan, the principal town of Saipan, after the battle of 1944

nese town, with 13,000 inhabitants and stores, shops, automobiles and bicycles. Within 17 years the Japanese population on Saipan multiplied from a "handful" to 20,000 and outnumbered the indigenous population more than four to one.

Japanese treatment of the Chamorros and Carolinians was firm but always "correct," even friendly. The German system of political administration was liberalized, permitting some self-government. Although the Japanese classed the Chamorros and the Carolinians as "people of the third class," ranking below Okinawans and Koreans, they allowed them occupational opportunities of many kinds, including the professions, and respected their property rights. Land being in great demand by the Japanese, the native inhabitants found they could lease their holdings and taste the joy of living off rents. "Among the Chamorros, increasing differentials in wealth developed, and a few of the families with large holdings of real property became well-to-do, with large and well-furnished houses." It was the fashion, if one could afford it, to send one's sons to Japan for schooling. Japanese-Chamorro intermarriages were not uncommon. Living standards rose, and a steady flow of new luxuries came from Japan—adopted foods, bicycles, tools, footgear and so on.

Most of the Carolinians did not participate in these blessings, for they had had little to start with and ended up with even less. Unable to live on the rentals of their small properties, they yielded to the pressure to sell their few fields. After using up the proceeds of the sale, they had to find employment; since the average Carolinian had no occupational skill, he usually had to take work as a stevedore. The Carolinians' social organization began to break down: their "community houses" gradually disintegrated; their clan and lineage ties weakened.

Upon the outbreak of the Second World War the Japanese converted the island into a huge garrison. Chamorros and Carolinians were conscripted for noncombatant service; the church was commandeered as a military storehouse, "and the priests had a difficult time with the ever-suspicious police." In February, 1944, when U. S. forces took the Marshall Islands and prepared to move on to the Marianas, the Japanese garrison ordered the Chamorros and Carolinians to the farms and occupied their houses in Garapan. The battle for Saipan lasted from June 15 to July 9. In it 3,100 U. S. troops and nearly 24,000 Japanese were killed. Casualties among the Chamorro and Carolinian civilians were heavy. The people also lost everything they possessed; when at last they found refuge in the internment camps they were starving and in rags. Saipan was flattened and its economy devastated. And in the process of converting the island into a base for tens of thousands of troops, the U. S. military authorities had to do further damage to the land.

For two years the Chamorros and Carolinians were kept behind barbed wire. When, after the war, they were given their freedom, they found themselves in a strange world—an island covered with paved highways, stores, service buildings, pool halls, popcorn stands, garages, restaurants, Quonset huts and prefabricated structures of every kind. For a time Saipan was prosperous. Jobs were plentiful, and the skills required to fill them were quickly learned, especially by the Chamorros. The wages they earned could be spent on entrancing novelties—aloha shirts, lipsticks, bright fabrics, jukeboxes, fashion magazines, Sears Roebuck dress patterns, reconditioned jeeps, radios and such delicacies as Coca-Cola, beer and hamburgers. The islanders got on well with the occupation troops. Later the small administrative group sent in by the Navy established close relations with the Chamorros and Carolinians. Spoehr points out that the people of the island do not have an attitude "of suspicion and avoidance" of U. S. administrative personnel.

The U. S. authorities have made a conscientious effort to provide Saipan with good medical care, public health services and educational facilities, and also to permit the islanders to participate in the running of these activities. The nurses and technicians of the district hospital, the principal and most of the teaching staff of the large district school are Chamorros and Carolinians. Unfortunately there are not enough teachers. A parent-teachers association is flourishing; Spoehr remarks that, contrary to the custom in the U. S., at meetings of the Saipan P.T.A. the "men do all the talking."

On the political side, a self-governing municipality has been created. Saipan has a full-time mayor, elected by the Chamorros and Carolinians for a four-year term. He oversees the work of several executive departments, is the "principal point of contact with the administrative authorities" and serves as the judge of the municipal court. There is a "Congress" composed of 25 commissioners and councilmen, and there are civil and criminal courts. Unfortunately this machinery doesn't work very well. There are budget difficulties, struggles

between the legislature and the executive, deadlocks over appropriation cuts and frequent complaints of executive extravagance by the more conservative citizens. In time the Chamorros and Carolinians may learn to handle the mechanics of representative government. But they are most seriously handicapped by the lack of a stable economy.

When the military installations were closed in 1950, most of the Saipanese lost their jobs. There were no farms to return to; the sugar industry was gone; the fishing industry at best could not supply more than a small portion of the population's needs. Saipan suffered and still suffers from the depletion of land and plant resources. When the land was cleared to grow sugar cane, much valuable vegetation was destroyed. Other misfortunes included the killing of most of the coconut trees by beetles and the elimination of some of the best land by bulldozing and then covering it with crushed coral limestone, thus rendering it "permanently unusable for cultivation." And while the remaining land, if restored and carefully managed, would suffice to support Saipan's present population, a tragicomic "ownership tangle" has risen which stands in the way—or at least still did in 1950—of agricultural development.

In time Saipan may recover. Its people have acquired a considerable variety of skills under the successive German, Japanese and U. S. administrations. But for the present, at least, these skills are not much use to the islanders. Truck drivers, mechanics, watch and radio repairmen are not apt to find their services in great demand on Saipan, and the proprietors of pool halls, laundries, restaurants, popcorn stands and the like, who, for a brief period had done a thriving business, were in 1950 "on the verge of bankruptcy." The combined action of foreign rule and invasion has left the Saipanese with lands that are impoverished, skills that are inappropriate to existing resources, aspirations that cannot be realized.

Spoehr examines in detail what the roller-coaster changes through which the Chamorro and Carolinian people have gone in the past 50 years have done to their culture: how the individual, the family, the kinship system have responded. It is remarkable to see how much of the cultural fabric has remained intact, how tenaciously men have clung to beliefs, social practices, subsistence techniques and institutions rooted in tradition. Perhaps it is this tenacity, even more than the capacity for adaptation, that has enabled these two small peace-loving societies to survive. One cannot

blame them, however, for wondering whether they could survive another war to save civilization. Spoehr writes:

"I was talking with a Chamorro friend about his corn crop. Suddenly he said, 'I tell you, señor, I am afraid. I never say anything, but in my stomach I am afraid of war. We have seen it once and many people are anxious. When we hear talk of war, there is fear in us. We wonder whether it is worthwhile to clear the land and plant our crops. Yes, we are anxious and afraid.' "

Short Reviews

FRESH WATER FROM THE OCEAN, by Cecil B. Ellis and others. The Ronald Press Company ($5.00). This report, a model of exposition and clear thinking, was sponsored by The Conservation Foundation and prepared by members of the staff of Nuclear Development Associates, Inc. The problem was to determine the least expensive method (over a 30-year period) of extracting one billion gallons per day of water suitable for drinking and irrigation from the sea off California or Texas. (One billion gallons was the average daily water consumption of New York City in 1950.) Sea water contains close to 3½ pounds of dissolved chemicals for every 100 pounds, which is to say, 35,000 parts per million by weight. The investigators adopted 1,000 parts per million of dissolved solids as their standard of suitable purity. For extracting the impurity ions they studied various methods, among them gravity, magnetism or electricity; mechanical means such as pressure, periodic vibrations, rotation, heat, refrigeration; strainers; distillation, with solar heat, heat from the earth or tidal forces as possible energy sources; and chemical precipitation, adsorption or ion exchange. Each of these methods is so carefully and simply described that a reader without scientific or technical capacity can readily follow the argument. The report concludes that the electric-membrane method of separation promises the lowest cost. In this system "the trick is to place a large number of parallel membrane sheets between the plates of an electrolysis tank—with membranes of the type passing only negative ions and membranes passing only positive ions occurring alternately." The undesirable ions are lured into "trap layers," from which they can be flushed with a pump, and the fresh-water ions, left in the alternate compartments, can be drawn off for use. The authors believe that within 10 years it should be possible to extract fresh water by this method at a cost of about 30 cents per 1,000 gallons at a "cheap-power location." This price would be practicable for many large cities and industries in the U. S. The report points out, however, that such consumers usually have access to river water at a much lower cost. Moreover, no extraction method suggested so far is likely to be suitable for large irrigation projects, primarily because the volume of water required is large compared to the value of the crop. An uncommonly interesting book.

STEAM POWER ON THE AMERICAN FARM, by Reynold M. Wik. University of Pennsylvania Press ($5.00). REFRIGERATION IN AMERICA, by Oscar Edward Anderson, Jr. Princeton University Press ($6.00). Two readable and scholarly contributions to the history of U. S. technology. Steam power came into use in American agriculture in the early part of the 19th century, when steam engines were attached to rice threshers, cotton gins, sugar mills and sawmills. Fifty years ago great land dreadnoughts, some of them towering 12 feet high, rolled from farm to farm, driving large threshing machines through oceans of grain. The gasoline tractor of course has now almost entirely supplanted the steam engine. Wik's account is full of instructive and entertaining details, taken from contemporary newspapers and records. Anderson traces the advances in mechanical refrigeration from its origins in 1755, when a Scottish physician, William Cullen, invented a machine which made ice by reducing the pressure on water in a closed container with an air pump. The development of refrigeration technology has made itself felt in a dozen different ways; it has facilitated the growth of cities and influenced the geography and economics of fruit and vegetable growing, dairying and meat packing. Well-chosen illustrations add to the interest of each of these valuable monographs.

SCIENTIFIC PAPERS PRESENTED TO MAX BORN. Hafner Publishing Company Inc. ($2.50). A collection of 10 distinguished scientific essays was presented to the noted German physicist on his retirement from the Tait Chair of Natural Philosophy at the University of Edinburgh in 1953. They include papers on wave mechanics by Louis de Broglie, on the general theory of relativity by Erwin Schrödinger, on complex and arbitrary numbers by Hermann Weyl, and an unusually interesting debate on the *psi* function by Albert Einstein and David Bohm. Bohm is concerned with refuting Einstein's assertion of the "well-founded requirement that in the case of a macrosystem, the motion of the system should approach the motion following from classical mechanics." Einstein regards this requirement as violated by Born's probability interpretation of the quantum theory, which does not permit "an objective description of the individual system even on a macroscopic level."

HOW TO LIE WITH STATISTICS, by Darrell Huff. W. W. Norton & Company Inc. ($2.95). "It ain't so much the things we don't know that get us in trouble. It's the things we know that ain't so." Artemus Ward's aphorism is singularly applicable to the stewpot of statistical misinformation the average man carries in his head. This book is described as "a sort of primer in ways to use statistics to deceive"—ways practiced by advertisers, politicians, lobbyists, pollsters, commentators and "assorted medicine men." It skillfully exposes the sample with the "built-in bias," the trick of passing off as the "average" the mean, the median or the mode—whichever happens to fit the demonstration—the "gee-whiz graph," the semi-attached figure, the one-dimensional picture, the *post hoc, ergo propter hoc* argument. A fine example of the pitfalls of glib correlations is given by the statistician Helen M. Walker. Suppose you are investigating the relationship between a woman's age and some physical characteristic, say the angle of the feet in walking. The angle, it turns out, is usually greater among older women. "You might first consider whether this indicates that women grow older because they toe out, and you can see immediately that this is ridiculous." It seems that you must then conclude that women toe out more because they grow older. Actually this is just as false; you have overlooked another possibility: the truth is that "the older women grew up at a time when a young lady was taught to toe out in walking, while the members of the younger group were learning posture in a day when that was discouraged." Huff has written an amusing book, and some of the illustrations by Irving Geis are very funny. It is an important manual of civil defense—defense against the daily assaults of hordes of "statisticulating" gasbags.

HUNTED HERETIC: THE LIFE AND DEATH OF MICHAEL SERVETUS, by Roland H. Bainton. The Beacon Press ($3.75). Michael Servetus was a Spanish physician, geographer, Biblical scholar, theologian and physiologist who had the

What General Electric people are saying . . .

C. H. LINDER

Mr. Linder is Vice President in charge of Engineering

". . . We are moving today, I believe, in industry and education, toward a common area of agreement on what constitutes the right kind of education. Industry, which in the past might rightly have been accused of sometimes taking a narrow view of the proper goals of education, is taking a broad-gauge view. We are increasingly recognizing the need for people who have had an education that has both variety and depth in engineering, science, and the humanities.

Most certainly in industry, particularly in our technical work, we need people who are educated, not just informed. Any attempt on the part of a secondary school, and more particularly a college or university, to give instruction in current engineering practice rather than a training in the basic principles is doomed to failure from the beginning if for no other reason than that technology is changing and shifting so rapidly.

With the increase in volume and complexity of our technology, the need for people in engineering and applied science with advanced degrees has become greater and, in my opinion, during the years that are immediately ahead our economy is going to require a continued increase in the percentage of our technical people with advanced degrees.

The role of the man trained in applied science is becoming of ever-increasing importance in engineering. In fact, it is my belief that many of the engineering curricula are going, during the coming years, to tend to include a larger and more significant element of training in applied science rather than in many of the design or engineering practice courses now included. Industry does not expect the secondary schools and colleges to create specialists in specific knowledge, but rather all-round well-trained people who have understanding of basic principles. As individuals find interest and challenge in specific areas the specialists we need will become available.

at the University of the State of N. Y. Albany

J. P. DITCHMAN

Mr. Ditchman is with the Lamp Division

". . . Light—fundamental to farm production—is becoming the key to farm-crop control. Scientific use of lighting promises more startling benefits for mankind than some other areas of technology that are much more publicized.

Although the relationship of light to life has long been known, only recently have we learned enough about the way light enters the life process to apply it commercially. Just a few applications have begun to multiply the productive capacity on the farms, but what has happened so far has convinced many scientists and businessmen that great things are ahead. Even the farmer is having difficulty maintaining his customary reserve.

Areas of hazard, formerly accepted as unavoidable, are on their way to becoming areas of control. For management of radiant energy in the interest of better crops and favorable market timing has begun.

As our experience broadens, we may well be prepared to extend what we know about familiar problems to the newer, less familiar ones. Most of us naturally think of lighting in terms of human uses. The lightmeter is calibrated for human seeing and film sensitivity. But in dealing with light for plants, animals, insects, fish, fowl, and game, we must think in terms of only the specific energy relevant to each.

In this vast field, there's much more to find out. Each day we learn how to make more and better food for the undernourished peoples of the world. Our gains in the past two decades have been tremendous. The future holds much promise.

G. E. Review

R. S. NEBLETT

Mr. Neblett is Manager—Marketing, Turbine Division

". . . The electrical industry today is producing twelve times as much power per year with but five times the fuel needed thirty-three years ago.

This improvement in fuel consumption has not resulted from the work of any one group, but rather from the united efforts of the manufacturers of turbine-generators, boilers, and auxiliaries; power plant designers; and, above all, the faith, daring, and enterprise of the owners of the power plants. Specifically the improvement may be credited to higher turbine-generator efficiency, to the increased pressures and temperatures at which power plants have been built, to the use of reheat and regenerative cycles, to the increase in unit sizes, to the improvement in component efficiencies, and to the improved operation of the plants themselves.

The pressure at which steam turbines have been operated has doubled at least every 12 years, and the temperature has increased over this 50-year period on almost a straight line at 12 F per year.

The economy with which power has been produced, that is the kilowatt-hour per pound of coal, has improved from 2 to 3 per cent per year over this period. This rate of improvement, as expected, has and will continue to slow down somewhat as time goes on.

Therefore, whether coal, oil, gas, or atomic energy is used as the fuel, or even if the heat of the sun shining down on a reflector is the heat source, I believe you will be using a turbine to convert such heat energy into electric energy for a good many years to come.

at the American Power Conference Chicago

"singular distinction" of being burned by the Catholics in effigy and by the Protestants in actuality. Bainton, a professor of ecclesiastical history at Yale University, has written a highly readable account of his life. Servetus was born in 1511, studied law at Toulouse and medicine at Paris and became an editor for a scientific publishing house in Lyons. He had written an essay "On the Errors of the Trinity" which set orthodox ecclesiasts on his tail. By changing his name and keeping on the move he managed for quite a few years to elude those who were outraged by his opposition to Trinitarianism and infant baptism. He has been credited with being the discoverer of the pulmonary circulation of the blood, but his claim to priority is not clear. In a theological work, the *Christianismi restitutio*, he announced in 1553 his theory that the "vital spirit is generated from a mixture made in the lungs of the inspired air with the elaborated refined blood, which is communicated from the right ventricle to the left"; it thereby gains its "bright hue." It was this work that brought about his arrest and a trial before the Inquisition at Vienne. Before sentence could be executed, Servetus made his escape by courtesy of a jailer who, seeing him garbed in a velvet nightcap and fur bathrobe, and not suspecting that he was fully dressed underneath, gave him a key to the prison garden where "prisoners of rank" were allowed to walk. After his escape the tribunal ordered Servetus punished in effigy: his picture was "hanged for a moment to dull its sensibilities and was then burned." He was later captured in Geneva and again tried and condemned under the auspices of Calvin. On October 27, 1553, on a "pile of wood still green," he died in a slow flame. "Today," says Professor Bainton, "any of us would be the first to cast a stone against Calvin's intolerance; and seldom do we reflect that we who are aghast at the burning of one man to ashes for religion do not hesitate for the preservation of our culture to reduce whole cities to cinders."

THE FUTURE OF ARCHITECTURE, by Frank Lloyd Wright. Horizon Press ($7.50). This collection of lectures and essays summarizes Wright's attempts during the last quarter-century to define his concepts of an "organic architecture" embodying the ideals of living in a democratic society. Wright's literary work is much like his architectural creations: original, independent, full of energy and protest and vision, sometimes brilliant, sometimes—where inspiration has failed or ideas are imperfectly

grasped—merely extreme and furiously unconventional.

THE NEW CENTURY CYCLOPEDIA OF NAMES, edited by Clarence L. Barnhart with the assistance of William D. Halsey. Appleton-Century-Crofts, Inc., three volumes ($39.50). This is a wholly revised and greatly expanded version of the old *Cyclopedia* originally published in 1894. "The glory and the nothing of a name," in Lord Byron's phrase, are displayed in these 4,342 pages. They list and describe more than 100,000 persons, places, events, plays and operas, books, literary characters, works of art, mythological figures, legendary persons and places. Here you can learn about Lily Adams Beck and the area of Bechuanaland; the plot of *As You Like It* and the origins of the Zyrenians; the careers of Babe Ruth, Tippoo Sahib and the less known Assyrian king Assuretililaniukinni; the population of Krk; the adventures of Hop-o'-my-thumb; the examples of Pithecanthropus; the purposes of the Society of Medical Jurisprudence; the ruling in United States *v.* Wong Kim Ark; the scope of the capital gains tax; the date of the discovery of the asteroid Doris. You will be as startled by some of the items included as by some of the omissions, but on the whole you will find these volumes not only a first-class compendium of facts but a wonderful garden for browsing and dalliance.

THE SCIENTIFIC ADVENTURE, by Herbert Dingle. Philosophical Library ($6.00). Dingle, professor of the history and philosophy of science at University College, London, is a learned, lively and incisive critic of scientific thought. Trained as an astronomer, he has written textbooks, technical papers and popular books. He is known as a stinging and effective controversialist who is not afraid to challenge accepted opinions. This book is a collection of his lectures and essays on the history and philosophy of science. It discusses, among other things, astronomy in the 16th and 17th century, physics in the 18th century, cosmological theories, time measurement, the laws of nature, the rational and empirical elements in physics, the relation of science to ethics and religion. Dingle's flat, pragmatic approach to abstruse concepts clarifies things refreshingly—if you are persuaded by his analysis. He considers that the single purpose of scientific work is to "arrange experience into a rational system." Much insight and pleasure can be derived from his many-faceted book, whether or not one agrees with all his opinions.

THE AMATEUR SCIENTIST

About making a microscope, a new idea for a large telescope and other matters

Conducted by Albert G. Ingalls

Kenneth Uitti, a petroleum engineer of Westmont, Ill., has several hobbies, among them optics. Like most amateur opticians, he prefers making his own instruments to buying commercial products of higher quality at half the cost. It took him two years to make the microscope shown on the opposite page. Admitting that it leaves something to be desired when compared with the best research microscopes, he says the instrument has proved far more than "just handy" in his primary hobbies of metalworking and gunsmithing.

"I have always done a lot of rifle and pistol shooting," he writes. "That leads to amateur gunsmithing and to dreaming about accuracy and ballistics. If you shoot, you get curious about rifle scopes and spotting scopes. Hence my lathe has turned out several of each. It happens that I have always loved astronomy and accordingly have a three-inch refractor and six-inch reflector. It was while figuring the reflector that I was bitten by the microscope bug.

"About 3:00 a.m. one night I was waiting for the mirror to cool in its cradle in preparation for the knife-edge test. As I sat there puffing a cigarette and thinking things over, I noticed a small scrap of brass tubing on the back of the bench and wondered, somewhat idly, what would happen if I shoved a Ramsden eyepiece into one end of it and a small plano-convex lens into the other. A bit of rolled cardboard served as a cell for the lens. The eyepiece fitted the tube nicely. When I pointed the contraption at a sprinkle of salt on the bench, I was amazed by the quality of the microscope image!

"At the moment I could not remember what a compound microscope looked like, and I had never really understood how they work. The next day I began scouring the libraries for books on microscope construction written for the amateur. The shelves were empty except for an occasional article telling how to do the job in two hours with spools for eyepieces and cardboard parts fastened together with airplane cement. I wound up by translating as much of the professional literature as possible into terms I could comprehend and working out the rest at the bench. The following description is based on the result. I hope it will encourage others to take up microscope-making and to pass their experiences along.

"It is only fair to warn the beginner that this is not an easy or inexpensive pastime. The finest microscope objectives stand at the pinnacle of the lens maker's art. The impossibility of duplicating them, however, should not discourage the amateur. His many hours of frustration will be compensated by the increased esthetic delight he will take thereafter in the master craftsman's accomplishment. If you have the patience of Job, a good screw-cutting lathe and a lot of spare time, plunge in. You will wind up with a useful piece of equipment and a firsthand knowledge of one of the most elaborate and interesting optical instruments known.

"In its essentials microscope theory is not difficult. The apparent size of an object can, in general, be enlarged in two ways: (1) by bringing the specimen closer to the eye, so that the image covers a larger portion of the retina; and (2) by projection, as in the case of the magic lantern. The compound microscope combines the two methods. A brilliantly lighted specimen, the counterpart of the magic lantern's slide, is brought close to the microscope's objective lens, which acts as a small projection lens. Rays from the object come to focus at a plane near the top of the instrument's tube. If a disk of ground glass is held in the position of this plane, the enlarged image can be seen—just as in a camera. This image, with or without the screen, can now be magnified further by bringing the eye close to it. Another lens, called the eyepiece, is necessary because the normal eye cannot see clearly at distances closer than about 250 millimeters (about 10 inches). The total of the two magnifications will be equal to the actual increase in the size of the projected image multiplied by the apparent increase caused by viewing the projected image at close range.

"Thus it is apparent that the microscope's objective lens does not differ in principle from the familiar projection lens or the lens of a camera. It projects an enlarged picture of the specimen. It is not unlike a telescope objective, except for its much smaller size and shorter focal length. The microscope, camera and telescope lenses all bend the rays from an object into focus at an image plane. In the case of the telescope the object is distant and a small image of it is formed relatively close to the lens. In the camera the two distances—from object to lens and from lens to ground-glass screen—may approach equality. They can be made equal in many cameras equipped with extension bellows, and the object is then photographed full size. The microscope goes to the opposite extreme. The specimen is brought close to the lens, within a small fraction of an inch in the case of high-power objectives. An enlarged image is then projected on a plane several inches away.

"Although the 'primary' or 'aerial' image is formed near the top of the microscope's tube, it appears to be down near the bottom when viewed through the eyepiece. This 'virtual' image is an optical illusion. Its phantom position is explained by the fact that we are accustomed to seeing objects clearly only when they are at least about 10 inches away. The position of the virtual image is useful in establishing the power of the microscope.

"When the statement is made that microscopes make objects appear larger, it makes sense to ask: 'Larger than what?' Microscopists answer: 'Larger than they would appear if viewed at a distance of 10 inches, the position of the virtual image.' The power of a microscope is arbitrarily defined as the number of apparent diameters an object would

have to be increased at 10 inches to equal its apparent diameter as represented by the virtual image. An eightfold magnifier, for example, makes an object which appears to be an eighth of an inch across at 10 inches appear a full inch in diameter.

"From practical considerations, it is desirable to design compound microscopes so that the plane of the primary image is formed at a prescribed point within the tube, just as the screen in a motion picture theatre is at a fixed distance from the projector. I designed my instrument for a projection distance (an 'optical tube length') of 180 millimeters. Most commercial objective lenses are corrected to work well at this distance; hence they can readily be interchanged with those you make yourself. Once this distance is standardized, it becomes a simple matter to calculate the power of an objective lens. The power is equal to 180 divided by the focal length of the objective in millimeters. The power of the eyepiece, however, is found by dividing its focal length in millimeters into 250 millimeters—the standard distance for nearest clear vision. Incidentally, by selecting lenses of proper focal length you can increase the magnification as much as you please, but, as with telescopes, beyond a certain point further power serves no purpose. Each objective lens can resolve only a limited amount of detail. Beyond this limit of resolution the picture becomes fuzzy.

"The optical train and tube are shown in cross section in the accompanying illustration [*see next page*]. *A* designates the aerial plane where the primary image falls—12 millimeters below the top of the tube and below the point against which the eyepiece shoulders. In use the eyepiece is shoved all the way against the shoulder and is never moved in focusing the instrument. Similarly the objective cell is built to shoulder against the bottom of the tube—at a distance 32 millimeters beyond the 'back focal plane' (*B* in the diagram) of the lens, where a bundle of parallel rays entering the objective comes to focus. The difference between the eyepiece and the objective shouldering distances, when subtracted from the optical tube length, gives the mechanical length of the tube—160 mm.

"Simple lenses for the instrument can be made by the methods described in *Amateur Telescope Making—Advanced*, or purchased at a few cents each from supply houses such as Edmund Scientific Corporation of Barrington, N. J., or A. Jaegers of Lynbrook, N. Y. High-power objectives can be purchased separately from dealers in microscopes and are available on the secondhand market.

"In designing the cell for simple objective lens combinations it is necessary to calculate several principal dimensions. The distance u between the object and objective—at which the primary image is brought into focus at plane A—is equal to:

$$u = \frac{(f_o + 180) f_o}{180}$$

"If two lenses are used for the objective, the equivalent focal length will be:

$$f_e = \frac{f_1 f_2}{f_1 + f_2 - s}$$

where s is the spacing between the lenses and f_1 and f_2 are the focal lengths of the two lenses. The object-image formula for such a combination will be:

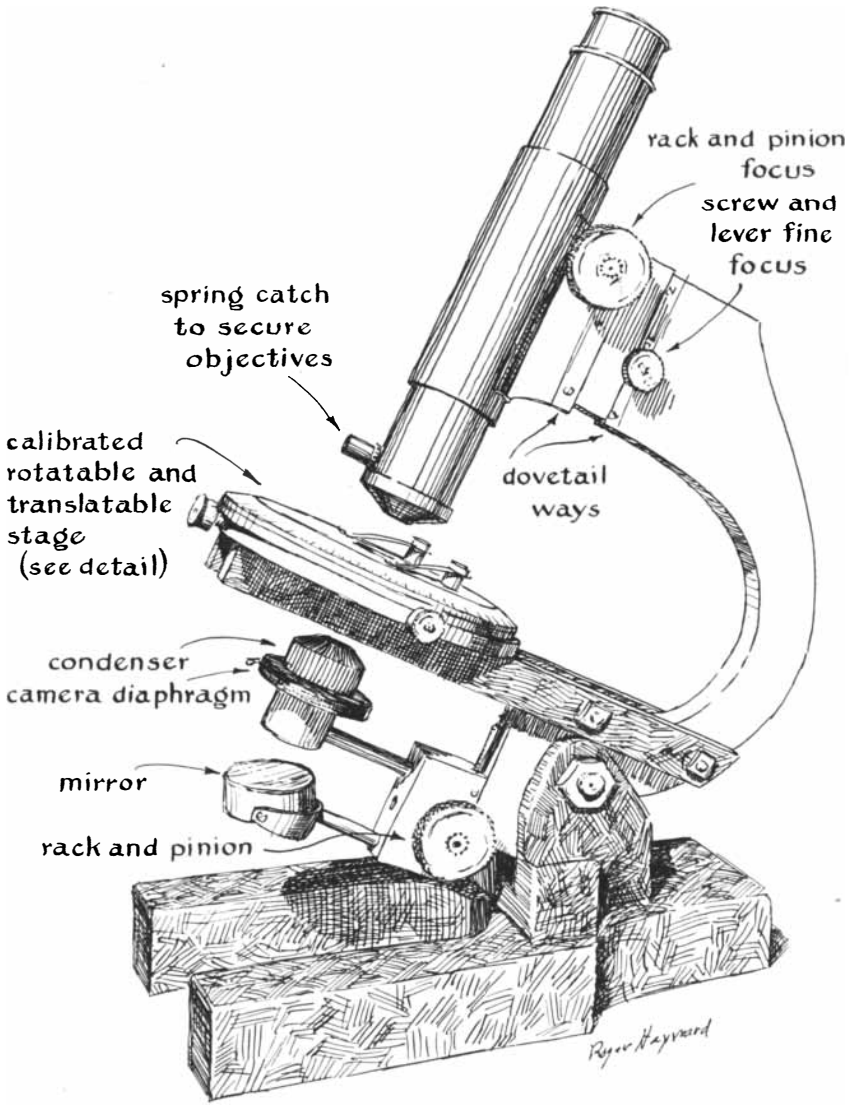
$$v = \frac{f_2\,(su - sf_1 - f_1 u)}{su - sf_1 - f_2 u + f_1 f_2 - f_1 u}$$

where f_1 is the focal length of the lens toward the object and f_2 is that of the lens toward the image.

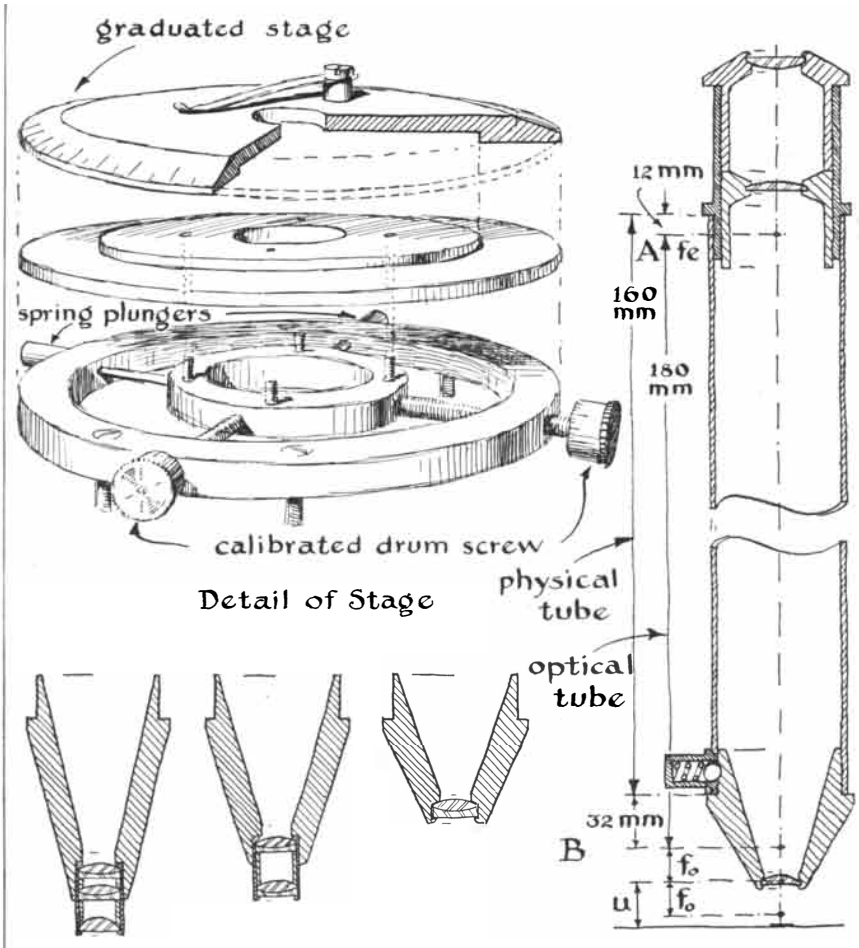
"The illustration shows a Ramsden eyepiece for simplicity. In this eyepiece the image is outside the lens system. The focal length of the lens combination is that of the two-lens system given above. The focal plane will be at this distance in front of the lens system:

$$u = \frac{f_1 f_2 - f_1 s}{f_1 + f_2 - s}$$

where f_1 is the focal length of the lens nearer the objective and s is again the



A microscope made by an amateur



Details of a homemade microscope

lens spacing. When designed by this formula, eyepieces of the Ramsden type will be focused on plane A when shouldered against the upper end of the tube. For eyepieces where the image is inside the lens system, as in the Huygens type, it is best to treat the field lens of the eyepiece as a unit with the objective system, calculating the equivalent focal length of the whole. The image will be at a plane in front of the eye lens at a distance equal to the focal length of the eye lens. For the kind of microscope that an amateur may wish to build, the positions of planes A and B may not be critical. A fastidious hobbyist, however, may wish to build an instrument which will not preclude the use of good high-power objectives.

"Despite the faint 'rainbows' that surround the image, simple plano-convex lenses give surprisingly good results as objectives of low power—from 10 to 15. The convex side should face the eyepiece. A 10-power plano-convex would have a focal length of 18 millimeters when used in an instrument with an optical tube length of 180 millimeters. For a 20-power objective a single achromat can be used. It would have a focal length of nine millimeters. If two are used, with their surfaces almost touching, the focal length can be longer. Using the equivalent focal length formula for two lenses, where $f_1 = f_2$ and s is essentially zero, the focal length of each lens is 18 millimeters.

"The system of illumination comprises the remaining optical element of the instrument. Illumination is critical and its importance must not be underestimated. I use a light source consisting of a bulb in a ventilated housing. This throws a beam of light through opal glass to a small first-surface mirror which is swung from the substage mechanism. The mirror is simple to make by the methods outlined in *Amateur Telescope Making*, or it may be procured from the supply houses previously mentioned. Light is reflected upward through the stage to the object. Direct lighting is satisfactory for low powers but magnifications above 100 powers require a substage condenser lens capable of focusing a sharp cone on

the object. The iris diaphragm from an old camera can be added immediately below the specimen stage for controlling intensity, and means must be provided for raising and lowering the substage assembly. The effect of the substage condenser on resolution is amazing. Martin and Johnson's *Practical Microscopy* and *The Principles of Optics* by Hardy and Perrin give excellent treatments on condenser design and a review of them is a must if the amateur is to make real headway.

"Most of the glass elements of my microscope were installed in cells made from machinable (half hard) aluminum rod and secured in place by rolling a thin sliver of metal over their edges with a polished tool-steel burnisher—a practice which I do not recommend for really good objectives. Threaded retaining rings offer obvious advantages. The cells in turn are pushed into brass tubing and secured by threaded rings. The exposed aluminum surfaces were coated with flat black coach paint. (Incidentally, who can tell me about a simple home method of anodizing aluminum for black optical goods?)

"The mechanical parts consist of an arm which supports the microscope tube and which swivels about the inclination joint at the head of a pillar. The pillar is mounted integrally (welded) on the base. The arm also carries the stage and the substage assembly. It is a good idea to make the base out of one-inch plate, either sawed out or cut out with an acetylene torch. The arm should be sawed out of half-inch steel plate or, better, of aluminum, since much machining has to be done on it. The pillar should be of two vertical pieces of half-inch plate welded to the base. The inside surfaces should be parallel and smooth. The arm pivots to the pillar by means of an axle of drill rod half an inch in diameter, threaded on both ends and fitted with large round knurled brass nuts on each end. The stage is simply a four-by-four-inch piece of steel plate a quarter of an inch thick, with a half-inch hole through which the specimen slides are illuminated. If desired, a second plate can be fitted to the stage so that it can be rotated through 360 degrees.

"Care must be taken in aligning the rotating plate with respect to the optical axis, or objects centered on the crosshairs of the eyepiece will arc out of position when the stage is moved. If you really want to be fancy, a mechanical stage-centering device is not impossible to build. This requires a ring mounting with two screws of fine thread at right

angles to each other, fitted with calibrated drums. A spring-compression plunger acting at 135 degrees from the screws holds the stage in place. The addition of a mechanical centering device will also pay dividends as a micrometer for measuring small objects.

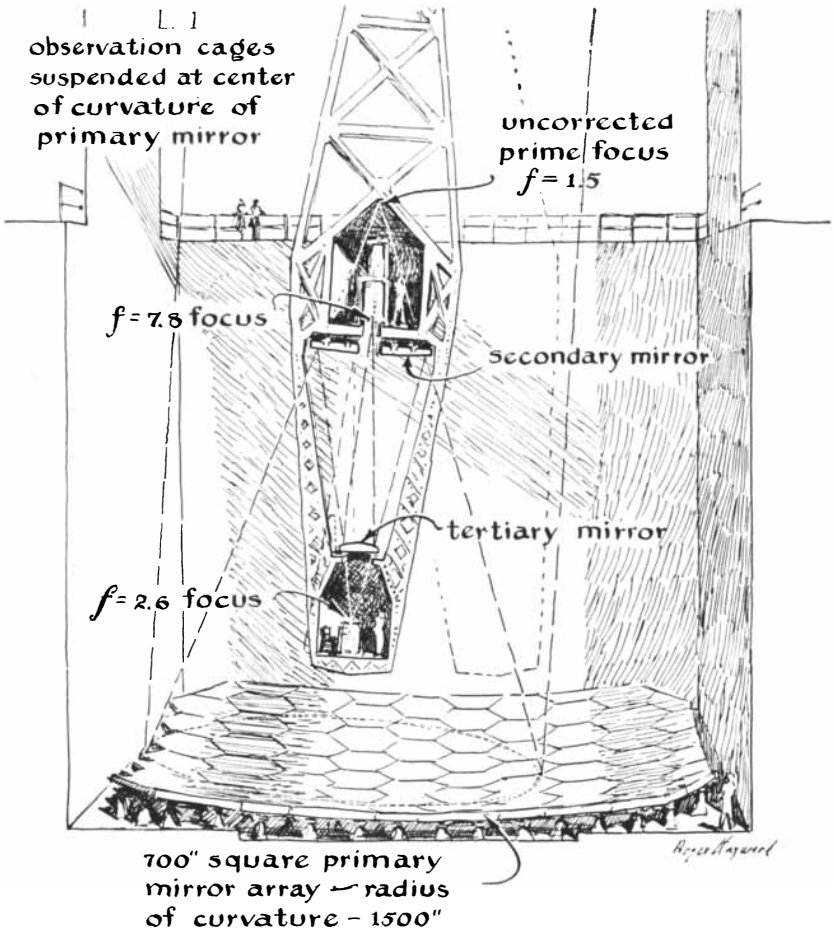
"Focusing can be accomplished by means of a rack and pinion. The rack is soldered to the tube. The pinion is placed through the arm and rotated by means of knurled brass wheels. In this scheme the moving brass tube fits into a stationary one which is secured to the arm and slotted for passage of the rack. I have had plenty of grief with the rough, 'clunky' motion of my spur-tooth rack and pinion. A helical one, if available, would probably be better. A soft rubber-roller friction drive, using no rack at all, might be smoother, but not as positive.

"The design of an original fine-focus mechanism presents a nice challenge to your inventive genius. Any device that will instantly go into action, regardless of the position of the coarse focus, and yet require many turns of a drum for a short movement of the objective, meets the specification. Many commercial instruments accomplish this by dovetailing the tube-supporting member into the arm. This member is raised and lowered by a lever of large mechanical advantage. A screw of fine thread bears against the long arm of the lever. The short end cams the tube up and down. The system may be spring-loaded.

"In presenting this account I have purposely omitted the fine details of method and dimension. In this business, as in making telescopes and other scientific instruments, most amateurs prefer to 'roll their own.' Once your microscope reaches the point, as mine now has, where you can use it as a magnifying viewer, you are ready to proceed with refinements and accessories. In one respect the home-built microscope is like an oil painting. In the fond hands of its creator it is never really 'finished.'"

Nearly all the mechanism of a large telescope of conventional type, such as the 200-inch, exists for moving the massive main mirror. In the unconventional zenith telescope proposed by Guido Horn-D'Arturo and others the main mirror is fixed to the earth at the bottom of a pit, and only auxiliary mirrors or the lightweight photographic plate move. This greatly limits the telescope's range, but it also greatly reduces the cost, since the main mirror no longer need be thick to be rigid. Two designs for zenith telescopes, one of them a concave-secondary combination of Gregorian type proposed by Lyle T. Johnson of La Plata, Md., were described in this department last month. Johnson now adds a zenith Cassegrainian [*see illustration on this page*]. Extending upward from the north and south edges of the pit are two piers. One is higher than the other, so that the sloping polar axis which spans them may parallel the earth's axis. The observing unit in the drawing hangs from the center of this span. It can be inclined and set anywhere within a range of 7¾ degrees in celestial latitude, that is, to the reader's right or left. Once set, it is slowly driven in longitude (away from the reader) to offset the earth's rotation. The circular field of view of its mirrors is 500 inches in diameter, but the square primary fixed mirror is 700 inches wide. The photographic plate therefore receives full illumination on a given image during 200 inches or about a half-hour of west-to-east travel, and partial illumination for an hour before and after.

This telescope is the rare spherical *primary* Cassegrainian, not the familiar spherical secondary, or Dall-Kirkham type. Bernhard Schmidt used the combination on the Cassegrainians that he built and sold when working as a free lance before he invented his famous Schmidt camera. It was also used on the 20-inch working model of the 200-inch, though only because a finished spherical mirror happened to be on hand; the aim in that case was mainly to test the mounting.



The Johnson zenith Cassegrainian telescope

Not all amateur astronomers are convinced that the evil effects of diffraction are as hopelessly incurable in optics as is sin in human beings. In this department for the issues of May and August, 1951, Edwin Emil Webb, William M. Sinton and others wrestled manfully with this supposedly ineradicable form of original sin. Now Arthur S. Leonard of the College of Agriculture at the University of California in Davis, a member of the amateur "Esoteric Order of Ray Tracers," proposes a practical experimental attack on diffraction effects for trial by telescope owners during

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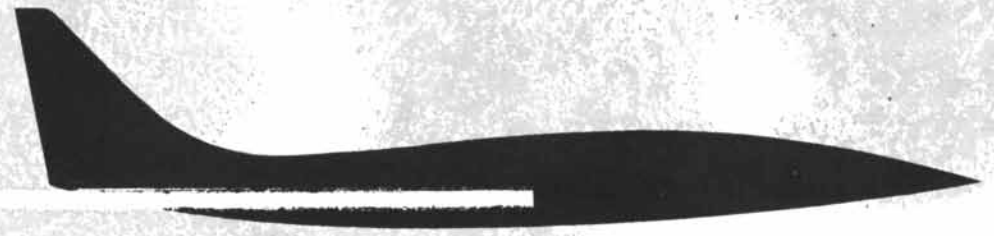

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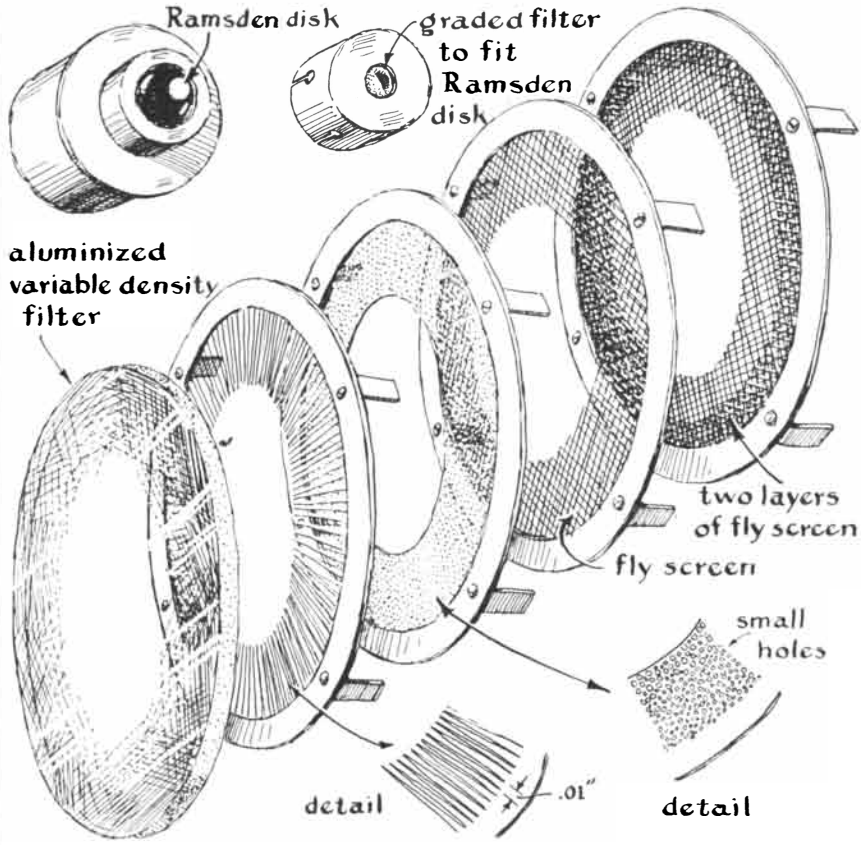

An ideal anti-diffraction mask

the present apparition of Mars. He writes:

"The method might be described as 'diffraction pattern modification.' I did not know about Sinton's article at the time I started experimenting to get rid of the diffraction pattern formed of a star in my telescope. I was using, in front of the telescope objective, an opaque diaphragm containing 19 circular holes arranged in a hexagonal pattern (one hole surrounded by six, and these surrounded by 12). I discovered by calculation, and verified by experiment, that if the diameter of the holes in the outer row of 12 was made one half of that of the other seven, the first and second bright rings of the diffraction pattern were practically eliminated. This suggested that if the transmissivity of the lens (or the reflectivity of the mirror) of a telescope were to be gradually reduced toward the edge of the aperture, the brightness of the rings of the Airy diffraction pattern formed by the objective would be greatly reduced. I reasoned that this might increase the sharpness of the central disk of the pattern. Any planetary image is no more than the mosaic of overlapping diffraction patterns formed on the retina of the observer's eye, each pattern corresponding to a separate point of light on the planet. Therefore anything which will increase the sharpness of an individual diffraction pattern should also increase the sharpness of planetary detail.

"I dreamed up several ways in which this shading off of the objective could be brought about. The first and most obvious solution was to reduce the thickness of the reflective coating gradually toward the edge of the mirror, as proposed by Sinton [*filter at left in the group on this page*]. It has the objection that the light-gathering power of the telescope would be permanently reduced, with serious loss in ability to show faint objects. Another solution is to add a tiny shading mask behind the eyepiece, at the Ramsden disk. This mask [*top of same group*] would be made of a thin piece of glass on which had been evaporated a thin reflective coating. The coating would have zero thickness at the center and gradually build up to let through say 25 per cent of the light at the edge of the Ramsden disk. This idea, though it has not yet been tried, has the advantage that the mask could be made removable from the eyepiece, or the eye-

piece could be changed, but it has the possible disadvantage of mutual interference between it and the observer's eyelashes. (We could use such a mask with only a few of our highest-powered eyepieces.) A variation of this idea would be to alter the design of an eyepiece, such as the Hastings solid ocular, to bring its last surface to the plane of the Ramsden disk, and then apply the shading reflective coat to that surface.

"The other methods that I have worked on might be described as 'shading by small obstructions.' One form of mask placed in front of the telescope has a row of sharp-pointed teeth extending inward for a distance of 40 to 50 per cent of the radius [*second filter from the left*]. Another consists of an opaque diaphragm having one large hole cut in the center (60 to 70 per cent of the diameter of the objective) and many small holes in the rest of it [*third filter from left*]. The effect of a gradual shading might be obtained if the small holes were extremely close together near the inner edge of the diaphragm and spaced more and more widely toward the outer edge. A third design, not shown in the drawing, uses a series of concentric rings of various widths and diameters supported on a spider. A fourth type employs wire screen for the obstructions [*fourth and fifth filters*].

"All of the masks that employ small but finite obstructions have one characteristic in common: they produce halos or line spectra around each point of light in the field. The angular distance from the central diffraction pattern to the closest of these halos is inversely proportional to the linear spacing of the teeth, small holes, rings or screen wires. By making this distance a sixteenth of an inch or less, the unwanted light can be made to fall farther from the center than the angular diameter of the largest planet that is to be observed. To push this light beyond the disk of the Moon, however, would require prohibitively close spacings.

"In the present apparition of Mars what is needed is something simple and easy to make in a short time. For this a wire-screen type of objective shading mask, known technically as an apodizing mask, is probably the best that I have thought up thus far. These masks use one, two or three layers of ordinary screen. I am using standard wire cloth with wires 12 thousandths of an inch in diameter and with 14 wires per inch one way and 18 the other. The general effect of a gradual reduction in transmission of

light toward the edge is obtained by increasing the number of layers of screen in the light path toward the edge of the aperture. Although this gives a reduction in light which occurs in steps instead of the ideally gradual manner, the harmful effects of the stepwise reduction can be reduced to a rather low value by locating the steps at near-optimum positions. For a single-screen mask to be used on a refractor, a hole between one half and two thirds the diameter of the objective should be cut in the center. The optimum probably is 60 per cent. With a reflector, the range of really useful diameters is from 55 to a bit over 60 per cent. For a double-screen mask for a refractor the optimum diameters are near 76 and 52 per cent. For a triple-screen combination these diameters should be 88, 76 and 52 per cent. These diameters should be useful with a reflector but somewhat better performance might be obtained from designs in which account is taken of the blind spot in the light path produced by the secondary.

"To make one of these masks, construct a frame of some sort to fit over the front of the telescope, attach the first screen to the frame with nails, screws or solder, cover the screen with paper on which has been laid out a circle the diameter of the largest opening to be cut, center the circle carefully, and attach the paper to the frame with Scotch tape. With a small cold chisel or a sharp sheet-metal punch, cut out the central part of the screen and paper along the line of the circle. After removing the paper, attach the second screen to the frame and cut the next smaller hole in the same way, and so on. In a double-screen mask, the mesh of the second screen should be turned 45 degrees with respect to the first; in a triple-screen combination, 30 and 60 degrees.

"These masks produce several different effects, some beneficial, some detrimental. First, the brightness at the center and all other points in the central disk of the diffraction pattern is reduced very appreciably. Second, the effective diameter of the central disk is increased, but to a lesser degree. The net result is a reduction of the total light in the central condensation of the Airy disk. On any kind of object—double star, planet and so forth—the increase in diameter must be regarded as a loss in resolving power. On very bright objects such as Mars, Venus or the Moon, the reduction in total light in the central disk may not result in a loss, and under some circumstances it may even help the observer to see more. On fainter objects, such as Jupiter and Saturn, the reduction in brightness of the image may be somewhat detrimental. The third effect is a very substantial reduction in the brightness and total light in most of the rings of the diffraction pattern relative to the brightness and total light in the central disk. The reduction is greatest in the first ring, and, since it contains almost as much light as the rest together, this effect must be regarded as a very substantial gain in resolving power, or at least in sharpness of detail. A fourth effect is a reduction in the seriousness of all kinds of aberrations—chromatic, spherical or those due to coma, distortion of the mirror or poor seeing.

"As we go from no mask to a single screen, to the double screen and so on, all these effects increase, but not all at the same rate. Therefore it is virtually impossible to predict by calculation alone which mask will give the greatest net gain in performance. It may well be that on one object one mask will work best, while on some other object another will give a maximum of improvement in detail. Also, since seeing is definitely a factor, and since the effect of seeing varies from night to night, from place to place, and from telescope to telescope (depending primarily on size), we may expect to find the optimum mask a highly variable quantity. This is where calculations based on simple theory leave us high and dry, and where we must look to extensive experiment by many observers. How about some of you other TNs making and trying these masks and reporting your findings?"

Last October Harvard University withdrew from the American Association of Variable Star Observers the annual income from a fund of $100,000 which has made its work possible for 21 years. This decision, which became effective at the end of the year, left the AAVSO with only $6,356 which had been raised by and mainly among its own members prior to 1931. The organization has new headquarters at 4 Brattle Street, Cambridge 38, Mass. Its goal is a fund of $250,000. To raise this sum the members would each have to contribute $600—an amount far beyond the means of the average amateur astronomer. Contributions of any amount from friends of amateur science will be welcomed by the AAVSO. The Association members keep a regular watch on variable stars year in and year out, each in an assigned portion of the sky. Their work has been invaluable to professional astronomers working on major problems.

INDEX OF ADVERTISERS

JUNE, 1954

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