SCIENTIFIC AMERICAN

RADIATION FROM A REACTOR

FIFTY CENTS
75 CENTS OUTSIDE THE AMERICAS
October 1951

Engines, too can have 9 Lives

At the heart of a diesel-electric locomotive are its carefully built electrical coils and armatures. When these break down, it is—literally—no go.

This used to happen about every 600,000 miles because conventional insulations stood just so much heat. But, today, engines can have 9 lives. The cycle can be boosted to roughly 5,000,000 miles by the use of amazingly tough insulations made with Fiberglas* yarns and silicones.

Why this vast improvement? Because Fiberglas yarns are made of pure glass in fiber form. And glass resists heat — can't burn, stretch or shrink — never deteriorates from temperature, moisture or age.

These valuable immunities are characteristic of all Fiberglas materials. That's why you see them in so many new uses each year. And in every form, from electrical insulations to decorative fabrics, Fiberglas products offer unique combinations of properties you can't get anywhere else.

Check the list below. See if it sets you on the track of a profitable idea. Then let's engineer it out together. Owens-Corning Fiberglas Corporation, 1610 Nicholas Building, Toledo 1, Ohio.

FIBERGLAS*

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

. . . IS IN YOUR LIFE . . . FOR GOOD!

With Fiberglas materials, either alone or in combination with other materials, you can have almost any combination of the following properties that your imagination can see a profit in:

CONTROL OF Heat or Cold . . Sound . . Dirt . . Electricity • RESISTANCE TO Moisture . . Corrosion . . Aging • LIGHT WEIGHT • RESILIENCY NONCOMBUSTIBILITY • DIMENSIONAL STABILITY • IMPACT STRENGTH TENSILE STRENGTH • EASE OF APPLICATION

***Fiberglas is the trade-mark (Reg. U. S. Pat. Off.) of the Owens-Corning Fiberglas Corporation for a variety of products made of or with fibers of glass.**

Electron tubes are the nerve ends of military intelligence — in systems set up and maintained by RCA Service Company field engineers.

Electron Tube with a military mind

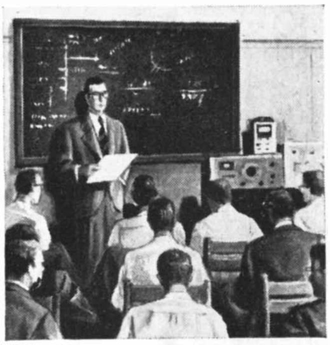
With the rapid advance of airplanes, tanks, fast ships, and mechanized weapons of war, a swift, sure means of *communication* and *detection* is as important as are the new weapons themselves. It is provided—by electron tubes and electronics.

So important is this area of military intelligence that RCA Service field engineers—here and abroad—have lifted their efforts to new peaks. Working with our Armed Forces, they install and maintain such *communications systems* as shortwave radio and portable radiotelephones. They work with systems of *detection*, such as radar. They help ships and planes *navigate* with loran and shoran. These engineers are the link between research developments made at RCA Laboratories—and America's military strength.

The number of RCA field engineers has *tripled* since World War II. And they serve where needed, wherever an electron tube's "military mind" can be of military use.

* * *

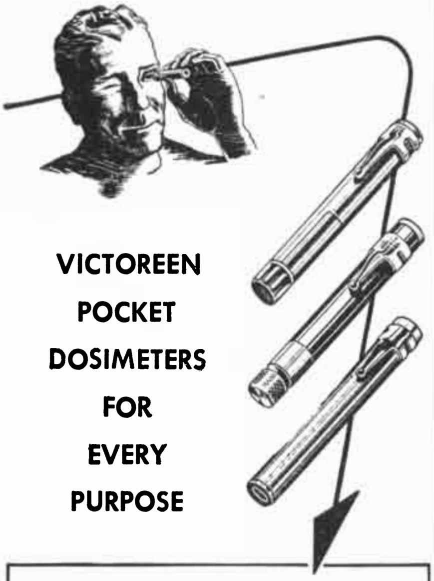
See the latest wonders of radio, television, and electronics at RCA Exhibition Hall, 36 West 49th Street, N.Y. Admission is free. Radio Corporation of America, RCA Building, Radio City, N.Y. 20, N.Y.



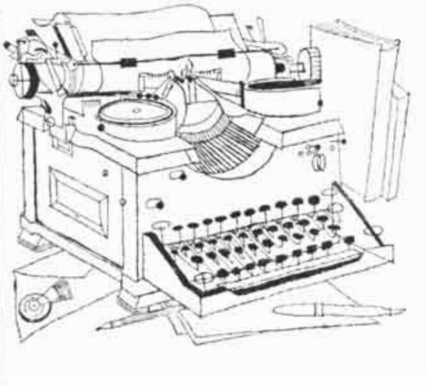
Practical training of military personnel—in classes, factory, and the field—is a basic part of RCA Service Company's work with our Armed Forces.

RADIO CORPORATION of AMERICA

World Leader in Radio — First in Television



LETTERS



Sirs:

It is unfortunate that an author of Stefan Jellinek's reputation should limit his article on artificial respiration [Scientific American, July] to an evaluation of the relative merits of the Schaefer and Sylvester methods. Any discussion of the serious problems involved that does not mention the work done during the past 10 years is of necessity incomplete. May I call to your attention the special article "Manual Artificial Respiration," by Gordon, Raymon, Sadove and Ivy in *The Journal of the American Medical Association* for December 23, 1950? The report of the Council on Physical Medicine and Rehabilitation on the same subject can be found in the same issue.

The following authors should have been mentioned in any paper which was to keep intelligent readers informed about recent progress: Kreiselman and his investigation of the manually operated bellows resuscitator, Sarnoff *et al.*, and their electrophrenic respirator, Flagg and his efforts to spread the knowledge of the prevention of asphyxia. It was Flagg who pointed out again and again that, for each accident victim whose death is due to a poor choice of the resuscitative method, ten will probably lose their lives due to unrecognized obstruction of the throat. It would have been desirable to have this point even more stressed than Dr. Jellinek has done in his article.

E. GEORGE BEER, M.D.

Veterans Administration Hospital
Butler, Pa.

Scientific American, October, 1951, Vol. 185, No. 4. Published monthly by Scientific American, Inc., 24 West 40th Street, New York 18, N. Y.; Gerard Piel, president; Dennis Flanagan, vice president; Donald H. Miller, Jr., vice president and treasurer. Entered at the New York, N. Y., Post Office as second-class matter June 28, 1879, under act of March 3, 1879. Additional entry at Greenwich, Conn.

Editorial correspondence should be addressed to The Editors, Scientific American, 24 West 40th Street, New York 18, N. Y. Manuscripts are submitted at the author's risk and will not be returned unless accompanied by postage.

Advertising correspondence should be addressed to Charles E. Kane. Advertising Manager, Scientific American, 24 West 40th Street, New York 18, N. Y.

Subscription correspondence should be addressed to Circulation Manager, Scientific American, 24 West 40th Street, New York 18, N. Y.

Change of address: Please notify us four weeks in advance of change. If available, kindly furnish an address imprint from a recent issue. Be sure to give both old and new addresses, including postal zone numbers, if any.

Subscription rates for U.S.A. and possesssions: 1 year, $5; 2 years, $9; 3 years, $12.50. Canada and Latin America: 1 year, $6; 2 years, $10; 3 years, $14. All other countries: 1 year, $8; 2 years, $12; 3 years, $16.

Sirs:

It was with considerable interest that I read Stefan Jellinek's article "Artificial Respiration" in your July issue, particularly in light of the fact that I have observed several overambitious attempts with the Schaefer method of artificial respiration in which the patient probably succumbed as much to the physical abuse of the method as to the brief suffocation before it.

I was somewhat surprised at Dr. Jellinek's approach to the susceptibility of humans to electrical shock, particularly in the light of a considerable amount of investigation that has gone on in the U. S. This research has resulted in consistent and extensive data as to the amount of electricity needed to bring on ventricular fibrillation. That Dr. Jellinek found poor correlation between the shocking voltage and animal fatalities is certainly not surprising, inasmuch as few physical phenomena are brought on by voltage directly. It is the current resulting from the application of voltage which damages animal tissue, affects the nerves or upsets muscular control in the body. Electrical resistance as well as voltage controls this current. The records of the National Safety Council would show that hardly a day goes by without some person whose feet are in a bathtub or hand on a water faucet being killed when touching a 110-volt, 60-cycle electric appliance. On the other hand, the writer has many many times accidentally come in contact with a 15,000-volt, high impedance, high-frequency source and suffered no more than a prickling sensation where the spark leaps to the skin. . . .

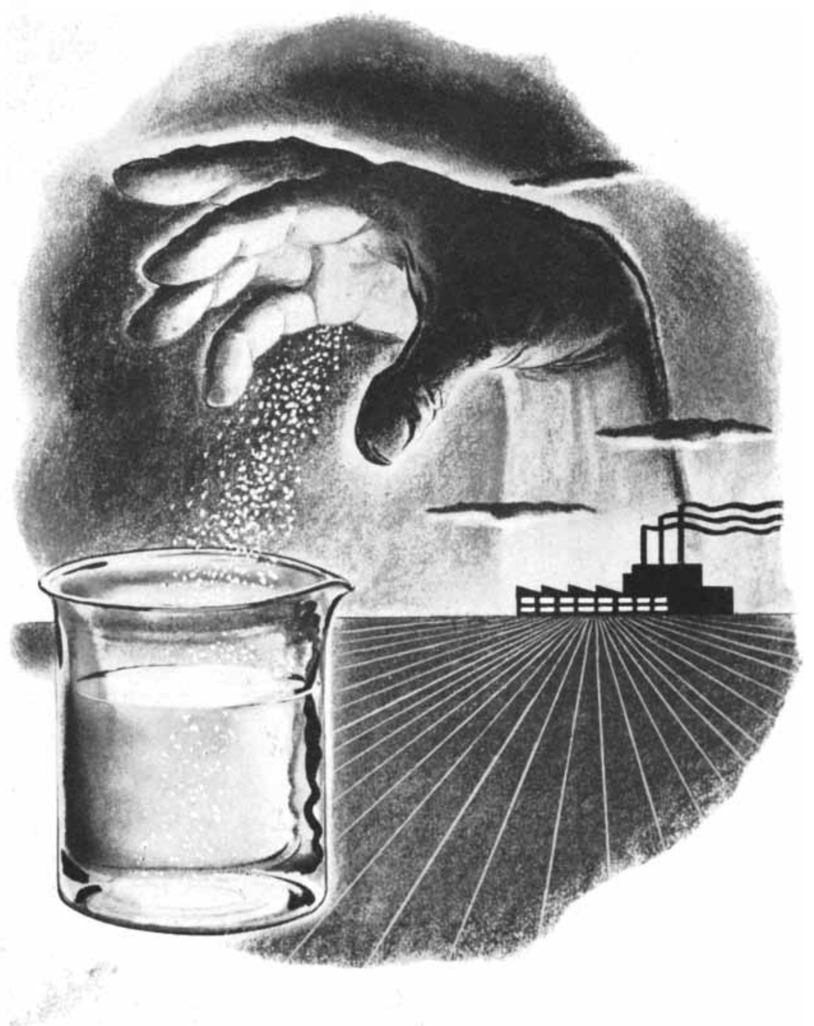
J. B. GARDNER

Seymour, Conn.

Sirs:

In my article I tried to stress that artificial respiration was an art that had to be learned by practical exercise, that the choice of method did not really matter


5046



greatly in the hands of the expert but that for general use the Sylvester method was probably the least dangerous. I am glad that Dr. Beer has again drawn attention to the over-all importance of a clear airway. We would hesitate, however, to recommend any method requiring implements of any sort, such as the electrophrenic method, which, incidentally, goes back to the researches of Duchenne in Boulogne during the last century and was first used successfully in resuscitation by Zangger in Zurich some 30 years ago. Purely manual methods are quite adequate and vital time is always lost when apparatus is used. Even under ideal conditions of resuscitation in operating theatres there is occasionally irreparable damage to the brain from oxygen lack during the one or two minutes it takes to decide on, and to start, cardiac massage.

Mr. Gardner is quite right in emphasizing that the amount of current is of vital importance in extreme cases, such as people electrocuted in a bath where their body is an ideal conductor for the flow of current to the earth; this is the basis of all protective insulation. We carried out many experiments and measurements along these lines some years ago but eventually came to the conclusion that Ohm's Law (current equals voltage divided by resistance) did not help in deciding whether a shock would be fatal or not except in extreme cases. On the one hand the resistance of the human skin varies enormously from place to place and from moment to moment; thus dry skin may insulate like leather, but a second later with sweat dilating the thousands of sweat ducts it conducts almost as well as a solution of salt in water. On the other hand, even under comparable conditions of voltage and current flow there is still a tremendous difference of response between different people, particularly with respect to fatality. Some would-be suicides, for instance, have survived even when, judging by the amount of gross tissue destruction, a great quantity of current must have passed through them; we think the answer lies in their preparedness for the shock.

STEFAN JELLINEK

Oxford, England

ERRATUM

The review by L. S. Penrose of Robert C. Cook's *Human Fertility: The Modern Dilemma* (SCIENTIFIC AMERICAN, August) contained the following statement: "Huntington's chorea does not account for 5 per cent of the patients in U. S. mental hospitals; it accounts for only about 1 per cent." This latter figure should be .1 per cent.

MEMO FROM: J.H.S.

TO: G.H.L.

Urgent — we must find a material right now to keep Department B in production.

Consider Pressed Glassware By Corning! GHL.

A few of the thousands of pressed glass articles and parts made by Corning are shown in this illustration. Loaded into molds of an infinite number of shapes, glass may well be the answer to *your* material problem. Corning can give you a wide variety of glass characteristics, design experience second to none and production facilities that will meet delivery schedules on time.

Yet, pressed glassware is just one phase of Corning's operations. We also blow glass into all sorts of shapes and sizes. We draw tubing for everything from pipe lines to thermometer stems. And some extremely complicated designs have been achieved by a combination of these processes.

Corning's research in glass has made glass important to industry. No other material affords better values in chemical inertness, high light transmission, high dielectric strength, hardness, smoothness, indifference to heat, etc. That's why glass by Corning is being used in so many unheard of spots today. So we say again, check with us or if you prefer, sign and mail coupon.

1 Mealpak dish
2 Sterilizer tray
3 Airport marker lens
4 Godet wheel
5 Watch glass
6 Laboratory desiccator
7 Neon sign insulator
8 Range burner plate
9 Coffee maker filter rod
10 Gauge and sight glasses
11 Lens blanks
12 Lighting lens
13 Stage light lens
14 Tops for percolators

1851 *Corning means research in Glass* 1951

Corning Glass Works
15 Crystal St., Corning, N. Y.

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

Please send me a copy of your booklet, "Glass, its increasing importance in product design."

NAME ________ TITLE ________

COMPANY ________

ADDRESS ________

CITY ________ ZONE ____ STATE ____

© 1951 SCIENTIFIC AMERICAN, INC

50 AND 100 YEARS AGO

OCTOBER 1901. "H. Becquerel has studied the radioactivity of uranium compounds at the temperature of liquid air. He shows that at that temperature the radiation is substantially the same as at ordinary temperatures. Uranium nitrate, when plunged into liquid air, or, better still, into liquid hydrogen, becomes luminous. This is an electric phenomenon due to molecular contraction."

"In close relationship to the electrical generation of ozone from atmospheric oxygen is the important question of the production of nitric acid from atmospheric air. The manufacture of nitrate of soda in this way is still undeveloped industrially. The idea is nevertheless alluring, for surely chemical science and chemical industry can be put to no higher or more fitting use than to help to increase the fertility of our fields. Those immense sources of motive power, the waterfalls of the world, which are now for the most part running to waste, require some great employment such as this, the production of nitric acid. If the quantity of nitric acid produced per kilowatt of power expended can be increased yet a little further—and such a development seems to be far from hopeless—this immense application of electricity would become profitable. The subject is certainly worthy of the serious attention of chemists."

"Faraday found, much to his surprise, that blood, although containing a large proportion of iron, was diamagnetic. A. Gamgee has now proceeded a step further, and examined the magnetic properties of the crystalline blood-coloring matter itself. He comes to the conclusion that the blood-coloring matter, oxyhaemoglobin, as well as carbonic-oxide haemoglobin and methaemoglobin, are decidedly diamagnetic bodies. The iron-containing derivatives haematin and acethaemin are, however, powerfully magnetic bodies. The differences in magnetic behavior between the blood-coloring matter and acethaemin and haematin point to the profound transformation which occurs in the haemoglobin molecule when it is decomposed in the presence of oxygen."

"In the heart of Africa, near the Semliki River, a new animal, the okapi, has been discovered which has attracted unusual attention among zoölogists. Stanley, at the time of his second journey in this region, had heard from the natives of a peculiar striped animal that was neither antelope nor zebra and yet as large as a horse. He never had an opportunity of seeing this creature. Sir Harry Johnston, the British plenipotentiary in Uganda, was more fortunate. He received from an officer named Ericsson, stationed in the Congo Free State, a complete hide with the hoofs, together with two skulls. With this material it was finally ascertained that the new animal was a ruminant related to the giraffe, but still more closely related to the Tertiary genera of *Halladotherium* and *Samotherium boissiori*. The animal is beyond a doubt a surviving species of an extinct genus closely related to the *Halladotherium* and *Samotherium* of the middle Tertiary, and may possibly be related to the now extinct many-toed ancestors of the horse."

OCTOBER 1851. "For all that has been said on this subject, our public murders are as common as ever. On September 21, the steamboat *James Jackson* exploded at Shawneetown, Illinois, and no less than 35 persons were either killed or wounded. The government inspection system is a mere sham. A law should be made compelling all steamboats to be built upon the low pressure principle."

"The steamboat *New World* ran from New York to Albany on Tuesday of last week; her running time was six hours and fifty-five minutes, the fastest steamboat run on record. This is something over twenty miles per hour for the whole distance, or nearly equal to our railroad speed."

"In this age of new ideas and new developments, no subject is of equal importance to that of sanatory reform. The sanatory condition of the people is a new science, because it takes cognizance of the durability of life, and examines those causes which shorten or prolong it. When thousands suffer from the fever, it examines into the causes of the plague, and seeks out the best means to remove them. If a disease like the cholera suddenly strikes down multitudes in our midst, it investigates the causes and endeavors to provide a remedy. It is the same with all other diseases—nothing escapes its searching scrutiny, for it includes not only medical, but religious, social, and political considerations. The

Your voice in Davy Jones' locker

To strengthen voices in the newest submarine cables between Key West and Havana amplifiers had to be built right into the cables themselves. With the cables, these amplifiers had to be laid in heaving seas; and they must work for years under the immense pressure of 5000 feet of water.

For this job, Bell Laboratories engineers developed a new kind of amplifier — cable-shaped and flexible, with a new kind of water-tight seal.

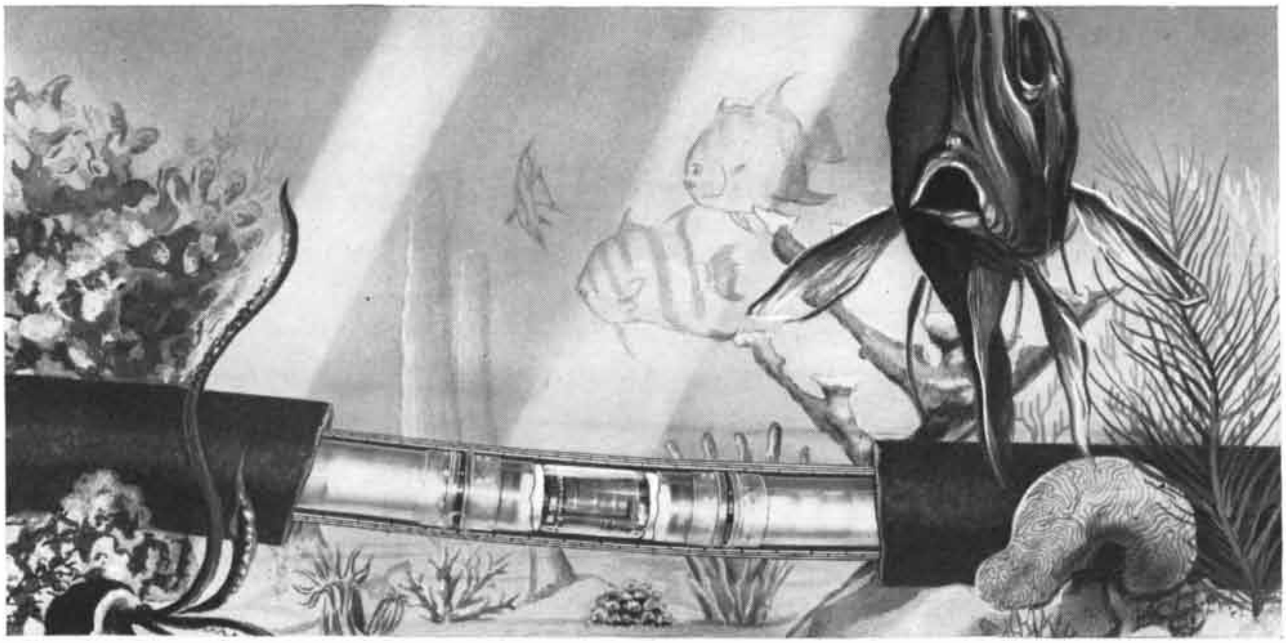
To serve far beyond reach of repair, they developed electron tubes and other parts, then assembled them in dust-free rooms.

The two cables — each has but two conductors — simultaneously carry 24 conversations as well as current to run the electron tubes.

With these deep-sea amplifiers, submarine cables carry more messages . . . another example of how research in Bell Telephone Laboratories helps improve telephone service each year while costs stay low.

BELL TELEPHONE LABORATORIES

• Exploring and inventing, devising and perfecting, for continued improvements and economies in telephone service.



Cutaway view of deep-sea amplifier. Tubes and other elements are housed in plastic cases then enclosed in interleaved steel rings within a copper tube. Layers of glass tape, armor wire and impregnated fiber complete the sheath. Cable ship, shown right, payed out cable over large sheave at bow.

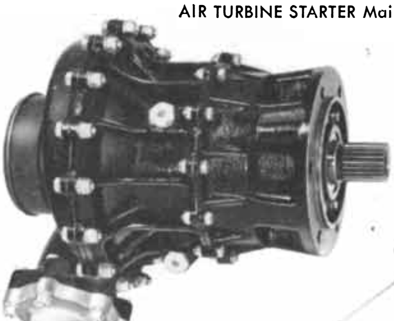
statistics of health are very useful, for by them we can form a good idea of the sanatory condition of cities, villages, and so on."

"By the latest news from California, the region appears to be in a desperate state morally, unless the papers greatly exaggerate the state of affairs. Lynching is quite a common practice. The gold appears to arrive in considerable quantities, and the crushing and washing of the quartz rock by machinery now give better returns than mining in the mountains."

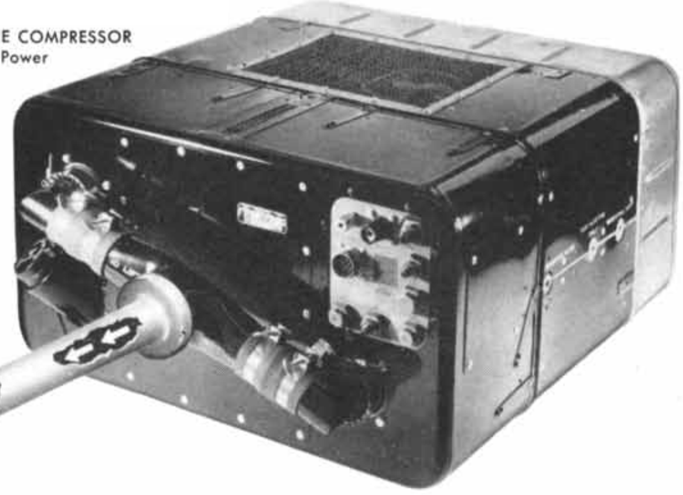
"A new style of vessels named clippers have come into existence for sea voyaging within the past two years. They are built more for making fast passages than for carrying cargo. They are beautiful in shape, and carry a great amount of sail. The vessel of this class which created the greatest excitement in this city was the *Flying Cloud,* built by Donald McKay, of Boston, and she has made the fastest run to San Francisco. She made the voyage from New York in 80 days. In one day she runs 374 miles, averaging about 16 knots per hour. This speed beats our fastest Atlantic steamers."

"The American Arctic expedition has returned after a cruise of more than a year, in which incredible hardships were endured, and in which the greatest courage, patience, and energy were displayed by all from the commander to the humblest mariner. To give some knowledge of the difficulties experienced in navigating the Arctic seas, the expedition was locked in ice for nine months. During this time they drifted 1,060 miles—a polar drift of unprecedented extent. During the time mentioned that dreadful disease, the scurvy, broke out. It is the opinion of all the officers that there are hopes that Sir John Franklin is yet alive. Captain Penny of the British expedition entertains the same opinion, and he has returned and asked a powerful steamship to go back and commence the search anew."

"We yet lack a great number of inventions to complete the catalogue of desirable improvements. We need a machine which could print as easily as we now can write; what a saving it would cause in steel pens and wretched scrawling! We now have machines to sow and machines to mow, but we need a machine to make our shoes and to mend them as well. More attention has perhaps been given to quantity than to quality in our modern improvements. A host of new machines have yet to be invented, and a host of improvements made on those machines now in use, in order that quality may show forth as pre-eminently as quantity."



AIR TURBINE STARTER Main Engine Starting



GAS TURBINE COMPRESSOR
Source of Power

PROVEN PNEUMATIC POWER!

An auxiliary power system for aircraft with a record proven by 2000 operational hours in the field

In addition to turbojet, turboprop and rocket engines—modern aircraft demand efficient *auxiliary* power for self-starting, pressurization, heating, cooling, the operation of electrical systems, radar, radio, hydraulic accessories.

AiResearch and the Navy Bureau of Aeronautics have developed and *proven* a low pressure pneumatic system to supply all these needs from a single independent source of power. The system utilizes bleed air from small gas turbine compressors (or from the main engines) to drive air and gas turbine motors, air turbine refrigerators and air starters. These units operate all mechanical accessories, cool the cabin and instruments and start the main engines. The system also supplies air for pressurization, heating and anti-icing.

It is efficient under all operating conditions.

Behind this system are:

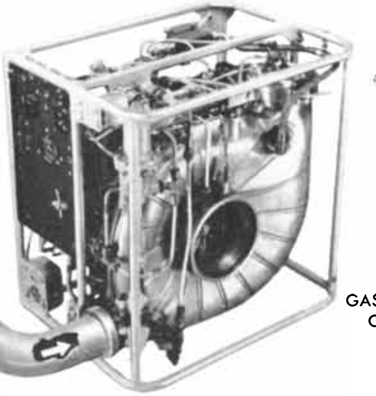
1. Eight years of research and development. **2.** Thousands of hours of actual running time in AiResearch laboratories, including official military qualification tests. **3.** Production experience and facilities. **4.** Application on 15 different types of jet and turboprop aircraft. **5.** 2000 hours of operation in the field.

Today this advanced-proven equipment is in production. It is available *now* to supply the all-purpose auxiliary power necessary for every type of high-speed, high-altitude aircraft being built or planned.

Whatever your problem in the field of pneumatic power, you are invited to consult with AiResearch.

AiResearch
DIVISION OF
THE GARRETT CORPORATION

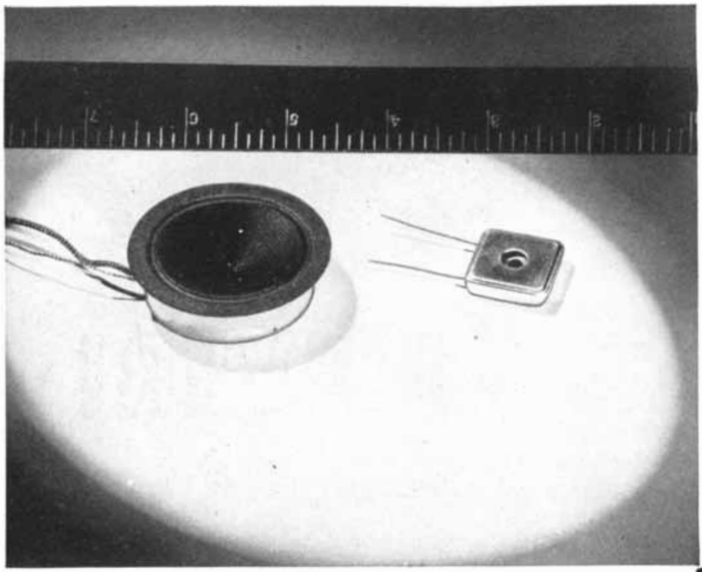
AiResearch Manufacturing Company, Dept. K-10, Los Angeles 45, California



GAS TURBINE MOTOR
Operates Mechanical Accessories

REFRIGERATION TURBINE
For Cabin Cooling

hearing aids have shrunk
to half their size



A Brush DEVELOPMENT

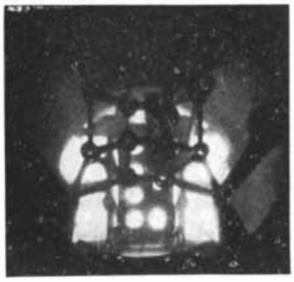
● Brush has been the leader in cutting the size of hearing-aid microphones. Now hearing aids are small, almost unobservable and, most important of all, do their job better. Deaf people no longer have to wear bulky, unsightly and hard-to-operate hearing aids.

The Brush Development Company for more than 21 years has studied the intricate, though powerful, piezoelectric effects of crystals. The principle of this smaller, more powerful microphone, as pioneered and developed by Brush, is that a tiny, jewel-like crystal converts sound waves into powerful electric signals. This is an example of continued engineering effort by Brush to make available to industry the many benefits and uses of piezoelectric materials, whether in hearing aids, measuring instruments or recording devices.

Manufacturers of

ACOUSTICAL EQUIPMENT
Microphones—General Purpose and Specialized
Hearing Aid Microphones
Earphones—Of Many Types
MAGNETIC RECORDING DEVICES
Tape
Plated Wire, Disc and Drum
Multichannel Recorders
Recording and Erase Heads
Memory Storage Units
Computer Components
RESEARCH AND INDUSTRIAL INSTRUMENTS
Universal Strain Analyzers
Surface Analyzers
Multichannel Direct Writing Oscillographs
AC, DC and Carrier-type Amplifiers
Uniformity Analyzers
Transient Recorders
PIEZOELECTRIC CRYSTALS
ULTRASONIC EQUIPMENT
Generators and Analyzers
Laboratory Equipment

OUR BUSINESS IS THE FUTURE
THE BRUSH DEVELOPMENT CO.
3405 PERKINS AVENUE • CLEVELAND 14, OHIO



THE COVER

The photograph on the cover is the first to show the interior of a nuclear chain reactor in actual operation. The reactor, which is located at Oak Ridge National Laboratory in Oak Ridge, Tenn., is immersed in a tank of water. Surrounding the fuel elements of the reactor, which are in the background, is a blue glow apparently resulting from the passage of fast electrons through the water. Called Cerenkov radiation, this glow is of special interest to the physicist (*see page 54*). The photograph was made solely by the light produced by the reactor itself. Although the photograph required an exposure of 25 minutes at *f*/11, the radiation from the reactor is readily visible to the naked eye.

THE ILLUSTRATIONS

Cover by Fred Williams, Oak Ridge National Laboratory

Page	Source
16-19	Irving Geis, from Interindustry Economics Division, U. S. Department of Labor, Bureau of Labor Statistics
21	Irving Geis
23	Edward D. DeLamater, School of Medicine, University of Pennsylvania
24-25	Katherine Brehme Warren, The Biological Laboratory, Long Island Biological Association
26-30	Irving Geis
45	Radiation Laboratory, University of California
47-49	Sara Love
50	Oak Ridge National Laboratory
53	Courtesy Eric Pickup, National Research Council of Canada
54	Sara Love
55	Courtesy George B. Collins, Brookhaven National Laboratory
56-59	Courtesy Ralph Colp, Jr.
62-64	David Stone Martin
68	K. Chester
70-72	Eric Mose
82	Roger Hayward

© 1951 SCIENTIFIC AMERICAN, INC

IDEA-PLASTICS

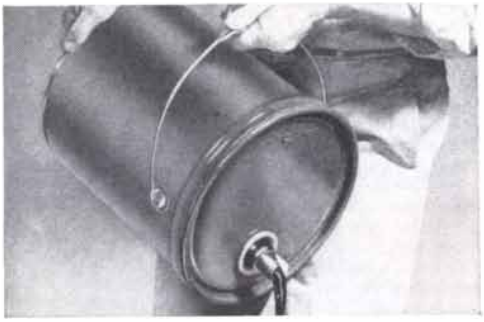
... from Du Pont Polychemicals Department

ALATHON* POLYTHENE RESIN

makes a new kind of closure

They've made pail closures out of many materials . . . but it wasn't until one manufacturer tried "Alathon" polythene resin that this truly unusual kind was developed. "Alathon" is almost completely inert . . . this new closure withstands any liquid that is shipped in commercially lined pails. For the same reason, "Alathon" won't contaminate the contents in any way. And because "Alathon" is also a flexible material, the closure could be designed to do two jobs. First, it provides an airtight, tamper-proof, moisture-proof seal. Then when the seal is cut, the closure pulls out easily to form a clean-pouring spout.

The properties of "Alathon" polythene resin make it a valuable plastic for other industries, too—for example, in the packaging, paper-coating, and electrical fields. And they suggest many new applications. A few possibilities are: as shoe components, as battery parts, and as a binder for non-woven fabrics.



There's a good chance your business may find opportunities for profitable future use in "Alathon" polythene resin . . . or perhaps in many of the other Polychemicals products. There are more than 100 of them—organic acids, amides, alcohols, ammonia, esters, resins, solvents and plastics.

Although demand for many of these products now exceeds supply, we will gladly discuss the availability of experimental quantities for developmental work.

Write for Technical Booklet on Polychemicals Products for Your Industry

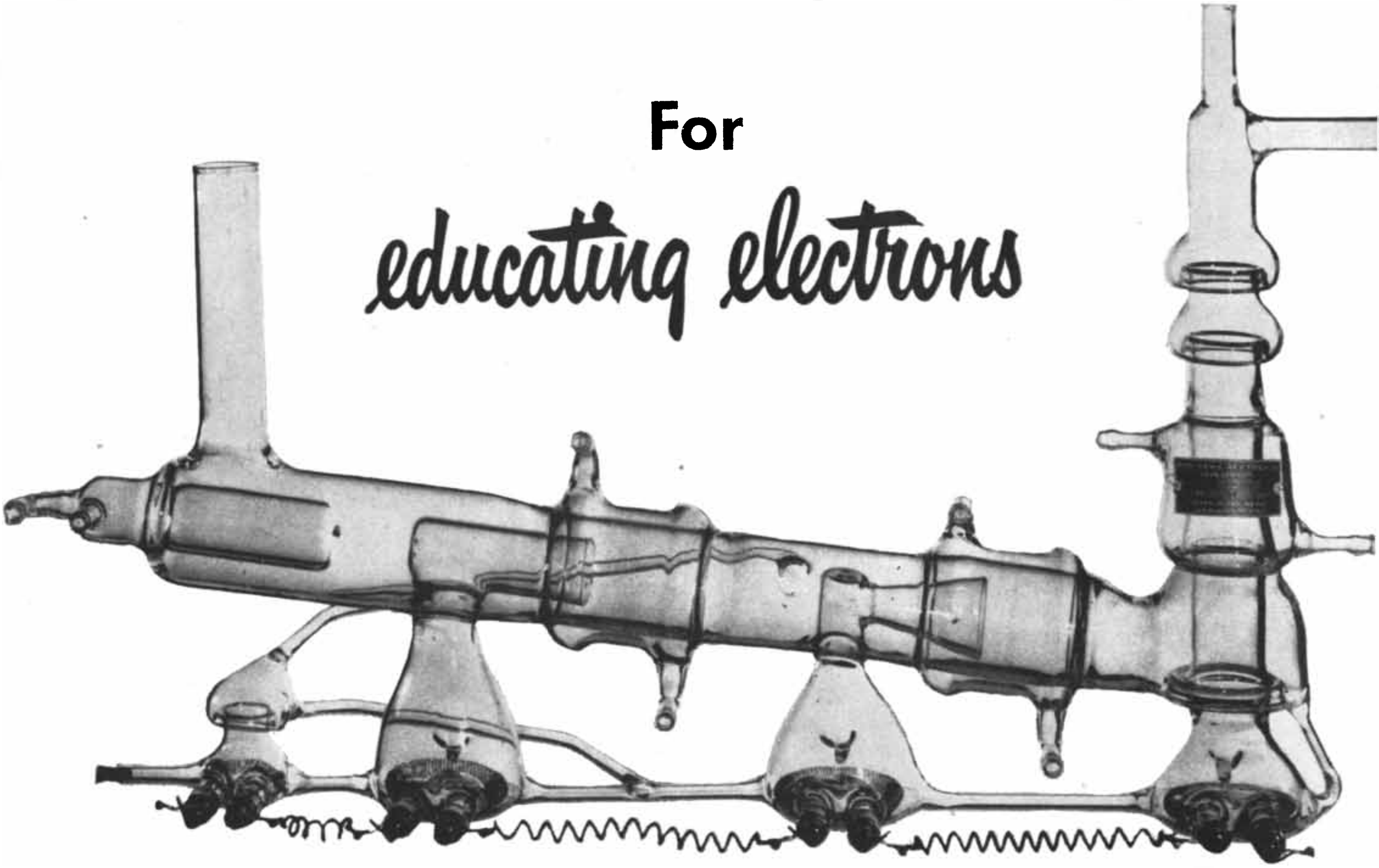
Technical bulletins on "Alathon" polythene resin and the chemicals and plastics used in your industry are available. Each product bulletin in the booklet presents physical and chemical properties, description, specifications, uses and possible applications, bibliography and other data. Write us on your business letterhead for your copy—and please tell us the name of your industry, or type of application that you have in mind.

E. I. du Pont de Nemours & Co., Inc.
Polychemicals Department, 1510S Nemours Building
Wilmington 98, Delaware

*REG. U. S. PAT. OFF.

DU PONT
REG. U. S. PAT. OFF.
BETTER THINGS FOR BETTER LIVING
. . . *THROUGH CHEMISTRY*

Polychemicals
DEPARTMENT
PLASTICS • CHEMICALS



For

educating electrons

Educated electrons are being called on for more and more difficult tricks in today's "vacuum" tubes. The higher the vacuum, the better they perform. The sharpest-focussed beams and the longest reliable operating lives are found in tubes exhausted to the utmost degree that modern technology permits.

For the development laboratory, a DPi glass diffusion pump as pictured here can give you the best vacuum that man can produce. The ultimate vacuum it gives without the aid of a cold trap is 5×10^{-8} mm. Hg. With a cold trap, 10^{-9} mm. Hg is attainable.

DPi invented the multi-stage fractionation principle and the Octoil®-S Vacuum Pump Fluids that make such vacuum possible. DPi's program to make really high vacuum work with ease and economy goes on continuously. Whether you're interested in a pound of low-vapor pressure gasketing, a chamber where experimental models of new electron tube ideas may be tried out quickly and inexpensively, or a complete exhaust system for a tube factory, your problems will receive careful attention. Merely write *Distillation Products Industries,* Vacuum Equipment Department, 751 Ridge Road West, Rochester 3, New York. (Division of Eastman Kodak Company).

high vacuum research and engineering

DPi

Also . . . vitamins A and E . . . distilled monoglycerides . . . more than 3400 Eastman Organic Chemicals for science and industry

© 1951 SCIENTIFIC AMERICAN, INC

SCIENTIFIC
AMERICAN

Established 1845

CONTENTS FOR OCTOBER 1951 VOL. 185, NO. 4

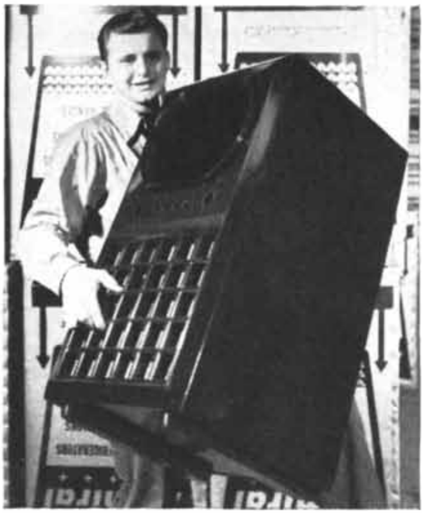
ARTICLES

DEPARTMENTS

Publisher: Gerard Piel
Editor: Dennis Flanagan
Managing Editor: Leon Svirsky
Contributing Editors: Albert G. Ingalls
James R. Newman
Art Director: K. Chester
Business Manager: Donald H. Miller, Jr.
Advertising Manager: Charles E. Kane

What's New at CRUCIBLE

about plastic mold steels



Cabinet for Admiral TV Console
Height: 34″
Width: 18″
Depth: 18¾″
Weight: 40 lbs.

two plastic TV console cabinets every five minutes for Admiral

Admiral (big name in radio, television, and electronics), Molded Products Corporation (pioneers in plastic molding), and Crucible (first name in special purpose steels), teamed up to produce sturdy, durable, economical TV cabinets. Admiral wanted TV console cabinets that not only would stand up under wear, but be mass-produced as well. Molded Products called on Crucible to provide the steel for the mold assembly.

a Crucible Plastic CSM2 Mold Steel forging that weighs 9300 pounds

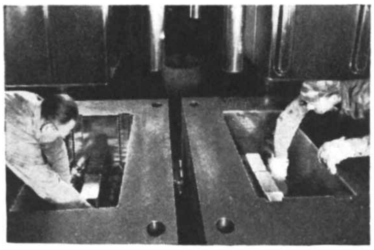
The initial development was put into operation two years ago, but recently Admiral wanted an even larger cabinet. As in the first mold assembly, Crucible metallurgists recommended Plastic CSM2 Mold Steel. The large cavity section of the 16,000-pound mold assembly required a mold steel forging that measured 41″x54″x20″ . . . and weighed 9300 pounds. This is one of the largest tool steel forgings ever made!

Two molds were built so that the 2500-ton hydraulic press could form two cabinets every five minutes.

The illustrations serve to show the size of the hydraulic press, the action of the plunger on the cavity, and the quality of the finished product. Compression molding as performed in the mold assembly is applied to a 40-pound plastic charge in each section of the cavity. The cabinet is molded in one piece including center shelving to support the television chassis. The power supply rests on the bottom of the cabinet. The speaker grille is integrally molded. Cored-in openings for the television window and controls, as well as cored studs for mounting are all part of this one operation.

8-ton mold assembly in action

It is a credit to Crucible Plastic CSM2 Mold Steel that this forging working around-the-clock has shown little wear . . . and maintained durable, uniform cabinets with few rejects.



Preparing for 40 lb. plastic charge. This is Crucible's 9300-lb. CSM2 forging.

write for more plastic mold steel information

Our metallurgists can help you apply Crucible plastic mold steels to your requirements. Write for literature. Crucible Steel Company of America, Chrysler Building, New York 17, N. Y.

CRUCIBLE first name in special purpose steels

51 *years of Fine steelmaking*

Spaulding Works, Harrison, N. J. • Midland Works, Midland, Pa. • Park Works, Pittsburgh, Pa. • Spring Works, Pittsburgh, Pa.
National Drawn Works, East Liverpool, Ohio • Sanderson-Halcomb Works, Syracuse, N. Y. • Trent Tube Company, East Troy, Wisconsin

SCIENTIFIC
AMERICAN

OCTOBER 1951 VOL. 185, NO. 4

Input-Output Economics

Concerning a new method which can portray both an entire economy and its fine structure by plotting the production of each industry against its consumption from every other

by Wassily W. Leontief

IF THE GREAT 19th-century physicist James Clerk Maxwell were to attend a current meeting of the American Physical Society, he might have serious difficulty in keeping track of what was going on. In the field of economics, on the other hand, his contemporary John Stuart Mill would easily pick up the thread of the most advanced arguments among his 20th-century successors. Physics, applying the method of inductive reasoning from quantitatively observed events, has moved on to entirely new premises. The science of economics, in contrast, remains largely a deductive system resting upon a static set of premises, most of which were familiar to Mill and some of which date back to Adam Smith's *The Wealth of Nations.*

Present-day economists are not universally content with this state of affairs. Some of the greatest recent names in economics—Léon Walras, Vilfredo Pareto, Irving Fisher—are associated with the effort to develop quantitative methods for grappling with the enormous volume of empirical data that is involved in every real economic situation. Yet such methods have so far failed to find favor with the majority of professional economists. It is not only the forbidding rigor of mathematics; the truth is that such methods have seldom produced results significantly superior to those achieved by the traditional procedure. In an empirical science, after all, nothing ultimately counts but results. Most economists therefore continue to rely upon their "professional intuition" and "sound judgment" to establish the connection between the facts and the theory of economics.

In recent years, however, the output of economic facts and figures by various public and private agencies has increased by leaps and bounds. Most of this information is published for reference purposes, and is unrelated to any particular method of analysis. As a result we have in economics today a high concentration of theory without fact on the one hand, and a mounting accumulation of fact without theory on the other. The task of filling the "empty boxes of economic theory" with relevant empirical content becomes every day more urgent and challenging.

This article is concerned with a new effort to combine economic facts and theory known as "interindustry" or "input-output" analysis. Essentially it is a method of analysis that takes advantage of the relatively stable pattern of the flow of goods and services among the elements of our economy to bring a much more detailed statistical picture of the system into the range of manipulation by economic theory. As such, the method has had to await the modern high-speed computing machine as well as the present propensity of government and private agencies to accumulate mountains of data. It is now advancing from the phase of academic investigation and experimental trial to a broadening sphere of application in grand-scale problems of national economic policy. The practical possibilities of the method are being carried forward as a cooperative venture of the Bureau of Labor Statistics, the Bureau of Mines, the Department of Commerce, the Bureau of the Budget, the Council of Economic Advisers and, with particular reference to procurement and logistics, the Air Force. Meanwhile the development of the technique of input-output analysis continues to interest academic investigators here and abroad. They are hopeful that this method of bringing the facts of economics into closer association with theory may induce some fruitful advances in both.

ECONOMIC theory seeks to explain the material aspects and operations of our society in terms of interactions among such variables as supply and demand or wages and prices. Economists have generally based their analyses on relatively simple data—such quantities as the gross national product, the interest rate, price and wage levels. But in the real world things are not so simple. Between a shift in wages and the ultimate working out of its impact upon prices there is a complex series of transactions in which actual goods and services are exchanged among real people. These intervening steps are scarcely suggested by the classical formulation of the relationship between the two variables. It is true, of course, that the individual transactions, like individual atoms and molecules, are far too numerous for observation and description in detail. But it is possible, as with physical particles, to reduce them to some kind of order by classifying and aggregating them into groups. This is the procedure employed by input-output analysis in improving the grasp of economic theory upon the

THIS TABLE SHOWS THE EXCHANGE OF GOODS

INDUSTRY

19 OTHER TRANSPORTATION EQUIPMENT
20 PROFESSIONAL AND SCIENTIFI
21 MISCELLANEOUS
22 COAL,

INDUSTRY PRODUCING	1 AGRICULTURE AND FISHERIES	2 FOOD AND KINDRED PRODUCTS	3 TEXTILE MILL PRODUCTS	4 APPAREL	5 LUMBER AND WOOD PRODUCTS	6 FURNITURE AND FIXTURES	7 PAPER AND ALLIED PRODUCTS	8 PRINTING AND PUBLISHING	9 CHEMICALS	10 PRODUCTS OF PETROLEUM AND COAL	11 RUBBER PRODUCTS	12 LEATHER AND LEATHER PRODUCTS	13 STONE, CLAY AND GLASS PRODUCTS	14 PRIMARY METALS	15 FABRICATED METAL PRODUCTS	16 MACHINERY (EXCEPT ELECTRIC)	17 ELECTRICAL MACHINERY	18 MOTOR VEHICLES
1 AGRICULTURE AND FISHERIES	10.86	15.70	2.16	0.02	0.19	—	0.01	—	1.21	—	—	0.05	*	0.01	—	—	—	—
2 FOOD AND KINDRED PRODUCTS	2.38	5.75	0.06	0.01	*	*	0.03	*	0.79	*	—	0.44	*	*	*	*	*	—
3 TEXTILE MILL PRODUCTS	0.06	*	1.30	3.88	*	0.29	0.04	0.03	0.01	*	0.44	0.09	0.03	—	0.01	0.02	0.05	0.15
4 APPAREL	0.04	0.20	—	1.96	—	0.01	0.02	—	0.03	—	—	*	*	—	*	*	*	0.10
5 LUMBER AND WOOD PRODUCTS	0.15	0.10	0.02	*	1.09	0.39	0.27	*	0.04	0.01	—	0.02	0.02	0.06	0.06	0.09	0.05	0.05
6 FURNITURE AND FIXTURES	—	—	0.01	—	—	0.01	0.01	—	—	—	—	—	—	—	*	0.01	0.10	0.03
7 PAPER AND ALLIED PRODUCTS	*	0.52	0.08	0.02	*	0.02	2.60	1.08	0.33	0.11	0.02	0.05	0.18	*	0.09	0.04	0.07	0.03
8 PRINTING AND PUBLISHING	—	0.04	*	—	—	—	—	0.77	0.02	—	—	—	—	—	0.01	0.01	0.01	—
9 CHEMICALS	0.83	1.48	0.80	0.14	0.03	0.06	0.18	0.10	2.58	0.21	0.60	0.13	0.12	0.18	0.13	0.08	0.20	0.11
10 PRODUCTS OF PETROLEUM AND COAL	0.46	0.06	0.03	*	0.07	*	0.06	*	0.32	4.83	0.01	*	0.05	0.90	0.02	0.04	0.02	0.03
11 RUBBER PRODUCTS	0.12	0.01	0.01	0.02	0.01	0.01	0.01	*	*	*	0.04	0.05	0.01	*	0.01	0.13	0.03	0.50
12 LEATHER AND LEATHER PRODUCTS	—	—	*	0.05	*	0.01	—	*	—	—	—	1.04	—	—	*	0.02	*	0.01
13 STONE, CLAY AND GLASS PRODUCTS	0.06	0.25	*	*	0.01	0.03	0.03	—	0.26	0.05	0.01	0.01	0.43	0.21	0.07	0.07	0.12	0.19
14 PRIMARY METALS	0.01	*	—	*	0.01	0.11	—	0.01	0.19	0.01	0.01	*	0.04	6.90	2.53	2.02	1.05	1.28
15 FABRICATED METAL PRODUCTS	0.08	0.61	*	0.01	0.04	0.14	0.02	*	0.13	0.08	0.01	0.02	*	0.05	0.43	0.62	0.34	0.97
16 MACHINERY (EXCEPT ELECTRIC)	0.06	0.01	0.04	0.02	0.01	0.01	0.01	0.04	*	0.01	—	—	0.01	0.07	0.28	1.15	0.17	0.63
17 ELECTRICAL MACHINERY	—	—	—	—	—	—	—	—	*	—	—	—	0.01	0.05	0.24	0.58	0.86	0.62
18 MOTOR VEHICLES	0.11	*	—	—	*	—	—	—	—	*	—	—	*	*	0.03	0.03	0.01	4.40
19 OTHER TRANSPORTATION EQUIPMENT	0.01	—	—	—	—	—	*	—	*	*	*	—	*	*	—	—	*	0.01
20 PROFESSIONAL AND SCIENTIFIC EQUIPMENT	—	—	—	—	—	*	0.01	0.03	0.01	—	—	—	*	*	0.04	0.04	0.01	0.07
21 MISCELLANEOUS MANUFACTURING INDUSTRIES	*	0.01	*	0.26	*	0.02	0.01	—	0.03	—	*	0.02	0.01	*	0.02	0.05	0.11	0.02
22 COAL, GAS AND ELECTRIC POWER	0.06	0.20	0.11	0.04	0.02	0.02	0.12	0.03	0.19	0.56	0.04	0.02	0.20	0.35	0.08	0.10	0.05	0.06
23 RAILROAD TRANSPORTATION	0.44	0.57	0.09	0.06	0.14	0.05	0.22	0.07	0.29	0.27	0.04	0.04	0.15	0.52	0.13	0.16	0.07	0.23
24 OCEAN TRANSPORTATION	0.07	0.13	0.01	0.01	0.01	*	0.02	*	0.04	0.09	*	*	0.01	0.08	*	*	*	*
25 OTHER TRANSPORTATION	0.55	0.38	0.08	0.03	0.14	0.04	0.12	0.03	0.10	0.47	0.01	0.02	0.07	0.16	0.03	0.04	0.03	0.07
26 TRADE	1.36	0.46	0.23	0.37	0.06	0.06	0.18	0.03	0.17	0.02	0.05	0.06	0.05	0.36	0.20	0.26	0.14	0.06
27 COMMUNICATIONS	*	0.04	0.01	0.02	0.01	0.01	0.01	0.04	0.02	0.01	0.01	*	0.01	0.02	0.02	0.03	0.02	0.02
28 FINANCE AND INSURANCE	0.24	0.15	0.02	0.02	0.08	0.02	0.02	0.02	0.02	0.13	0.01	0.01	0.05	0.06	0.04	0.05	0.04	0.02
29 REAL ESTATE AND RENTALS	2.39	0.09	0.03	0.10	0.02	0.02	0.03	0.06	0.03	—	0.01	0.02	0.02	0.06	0.03	0.04	0.03	0.02
30 BUSINESS SERVICES	0.01	0.63	0.07	0.10	0.02	0.06	0.02	0.06	0.42	0.04	0.02	0.05	0.01	0.03	0.05	0.09	0.06	0.08
31 PERSONAL AND REPAIR SERVICES	0.37	0.12	*	*	0.04	*	*	0.02	0.01	0.01	*	*	0.03	0.01	0.01	0.01	*	*
32 NON-PROFIT ORGANIZATIONS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
33 AMUSEMENTS	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
34 SCRAP AND MISCELLANEOUS INDUSTRIES	—	—	0.02	—	—	—	0.25	—	0.01	—	0.01	—	0.01	1.11	0.02	0.05	*	—
35 EATING AND DRINKING PLACES	—	—	—	—	—	—	—	*	—	—	—	—	—	—	—	—	—	—
36 NEW CONSTRUCTION AND MAINTENANCE	0.20	0.12	0.04	0.02	0.01	0.01	0.04	0.01	0.04	0.03	0.01	0.02	0.03	0.10	0.03	0.05	0.02	0.04
37 UNDISTRIBUTED	—	1.87	0.30	1.08	0.73	0.27	0.17	0.50	1.49	0.65	0.27	0.27	0.47	0.32	1.14	1.71	0.89	0.41
38 INVENTORY CHANGE (DEPLETIONS)	2.66	0.40	0.12	0.19	*	0.01	0.09	0.03	0.14	0.01	*	0.03	*	0.11	*	*	*	0.01
39 FOREIGN COUNTRIES (IMPORTS FROM)	0.69	2.11	0.21	0.28	0.18	0.01	0.62	0.01	0.59	0.26	*	0.04	0.14	0.62	0.01	0.05	*	0.02
40 GOVERNMENT	0.81	1.24	0.64	0.38	0.34	0.11	0.50	0.34	0.76	0.78	0.11	0.14	0.32	0.82	0.48	0.77	0.40	0.66
41 PRIVATE CAPITAL FORMATION (GROSS)	DEPRECIATION AND OTHER CAPITAL CONSUMPTION ALLOWANCES ARE INCLUDED IN HOUSEHOLD ROW																	
42 HOUSEHOLDS	19.17	7.05	3.34	4.24	2.72	1.12	2.20	3.14	3.75	5.04	1.08	1.20	2.35	5.53	4.14	6.80	3.41	3.39
TOTAL GROSS OUTLAYS	44.26	40.30	9.84	13.32	6.00	2.89	7.90	6.45	14.05	13.67	2.82	3.81	4.84	18.69	10.40	15.22	8.38	14.27

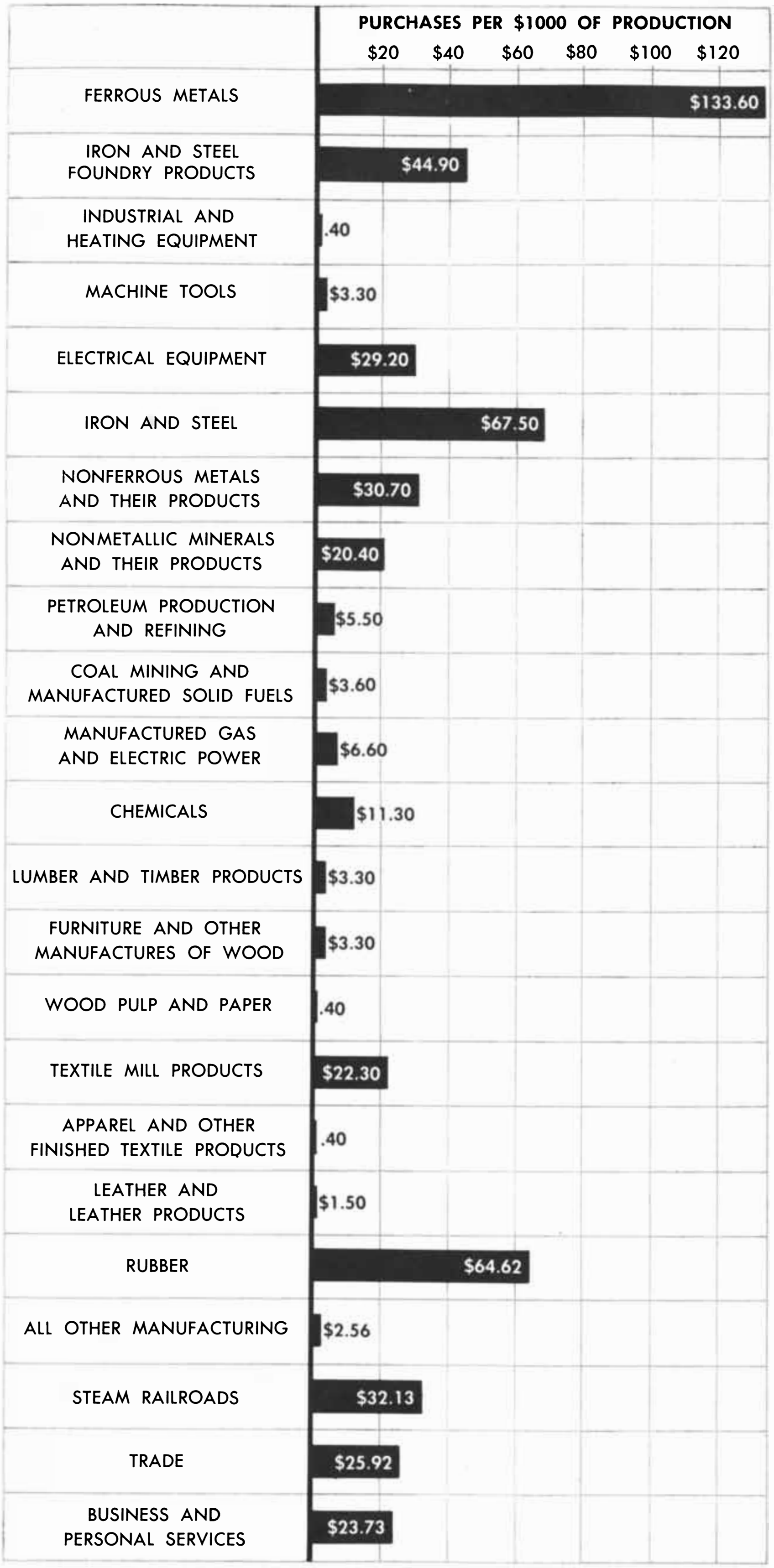
INTERINDUSTRY TABLE summarizes the transactions of the U. S. economy in 1947, for which preliminary data have just been compiled by the Bureau of Labor Statistics. Each number in the body of the table represents billions of 1947 dollars. In the vertical column at left the entire economy is broken down into sectors; in the

AND SERVICES IN THE U. S. FOR THE YEAR 1947

PURCHASING

																			FINAL DEMAND					
	EQUIPMENT	MANUFACTURING INDUSTRIES	GAS AND ELECTRIC POWER	RAILROAD TRANSPORTATION	24 OCEAN TRANSPORTATION	25 OTHER TRANSPORTATION	26 TRADE	27 COMMUNICATIONS	28 FINANCE AND INSURANCE	29 REAL ESTATE AND RENTALS	30 BUSINESS SERVICES	31 PERSONAL AND REPAIR SERVICES	32 NON-PROFIT ORGANIZATIONS	33 AMUSEMENTS	34 SCRAP AND MISCELLANEOUS INDUSTRIES	35 EATING AND DRINKING PLACES	36 NEW CONSTRUCTION AND MAINTENANCE	37 UNDISTRIBUTED	38 INVENTORY CHANGE (ADDITIONS)	39 FOREIGN COUNTRIES (EXPORTS TO)	40 GOVERNMENT	41 PRIVATE CAPITAL FORMATION (GROSS)	42 HOUSEHOLDS	TOTAL GROSS OUTPUT
—	*	*	—	*	*	0.01	—	*	—	—	—	—	0.12	—	—	0.87	0.09	0.17	1.01	1.28	0.57	0.02	9.92	44.26
—	0.01	0.02	*	0.08	0.01	0.03	0.07	0.01	—	—	—	*	0.25	*	0.02	3.47	*	0.42	0.88	1.80	0.73	—	23.03	40.30
0.01	0.05	0.08	0.07	—	0.01	0.01	0.03	*	—	—	*	0.03	*	—	0.01	—	0.05	0.52	0.06	0.92	0.10	0.02	1.47	9.84
0.01	*	*	*	*	*	*	0.02	*	—	—	—	0.02	0.02	*	0.01	0.02	*	0.15	0.21	0.30	0.28	*	9.90	13.32
0.03	*	0.06	0.06	—	0.01	*	0.03	*	—	0.14	*	*	*	—	0.11	0.01	2.33	0.35	0.17	0.17	0.01	0.04	0.07	6.00
0.02	*	—	*	—	—	*	—	*	0.04	0.08	—	—	*	—	—	—	0.20	0.20	0.08	0.03	0.05	0.57	1.46	2.89
0.02	0.08	0.07	*	*	—	*	0.57	*	*	—	*	0.06	0.03	—	0.68	0.06	0.17	0.31	0.04	0.15	0.06	—	0.34	7.90
—	*	—	*	0.04	*	0.02	0.10	0.03	0.21	—	2.45	0.03	0.17	0.01	0.01	0.03	—	0.68	*	0.07	0.16	0.09	1.49	6.45
0.02	0.05	0.17	0.06	0.03	0.01	0.02	0.07	*	*	—	0.01	0.20	0.22	*	0.03	0.04	0.64	1.25	0.30	0.81	0.19	—	1.96	14.05
0.01	*	0.01	0.47	0.27	0.09	0.45	0.20	*	0.01	0.78	*	0.06	0.06	*	0.01	0.01	0.62	0.36	0.06	0.68	0.18	*	2.44	13.67
0.01	*	0.04	*	*	—	0.13	0.06	*	0.01	*	—	0.07	*	—	*	*	0.06	0.47	0.09	0.17	0.02	0.01	0.71	2.82
*	0.01	0.01	*	—	—	*	*	—	—	—	—	0.03	0.01	—	0.01	—	*	0.29	0.11	0.08	0.03	0.02	2.03	3.81
0.01	0.03	0.06	0.02	0.01	*	*	0.04	*	—	—	—	0.02	0.01	—	*	0.06	1.74	0.36	0.10	0.21	0.02	0.01	0.34	4.84
0.43	0.07	0.20	0.05	0.20	—	0.01	—	*	—	—	—	—	*	—	0.15	*	1.19	1.24	0.16	0.77	0.02	—	0.02	18.69
0.10	0.07	0.04	*	0.03	*	0.01	0.06	*	—	—	*	0.03	0.01	—	0.06	0.02	3.09	1.44	0.21	0.39	0.05	0.28	0.95	10.40
0.22	0.03	*	0.03	0.06	—	0.01	0.01	—	0.02	—	—	0.15	*	—	0.07	—	0.51	2.24	0.37	1.76	0.18	5.82	1.22	15.22
0.12	0.03	0.02	0.02	0.04	—	0.01	0.01	0.05	—	—	0.01	0.09	*	—	0.04	—	0.77	1.27	0.25	0.44	0.17	1.75	0.93	8.38
*	—	—	0.01	*	—	0.13	0.02	*	—	*	—	1.05	*	—	0.07	*	0.04	0.67	0.40	1.02	0.15	2.98	3.13	14.27
0.30	—	—	*	0.04	0.08	0.13	—	—	—	—	—	*	—	—	0.01	—	*	0.46	0.02	0.32	1.25	1.20	0.17	4.00
0.02	0.18	0.02	*	—	—	*	—	*	—	—	0.01	0.05	0.18	—	0.01	—	0.02	0.24	0.03	0.18	0.08	0.26	0.62	2.12
*	0.03	0.16	*	*	*	*	0.01	*	—	—	0.15	0.16	0.05	0.05	0.11	0.02	0.03	0.68	0.04	0.19	0.08	0.51	1.89	4.76
0.03	0.01	0.03	1.27	0.44	*	0.09	0.49	0.01	0.06	3.15	*	0.31	0.16	0.05	—	0.22	0.03	0.02	0.03	0.35	0.20	—	—	9.21
0.04	0.01	0.03	0.15	0.41	*	0.06	0.08	*	0.01	0.42	0.03	0.03	0.05	*	0.03	0.25	0.71	0.30	0.08	0.59	0.33	0.27	2.53	9.95
*	*	0.01	*	—	0.22	—	—	—	—	—	—	—	—	—	*	—	—	*	—	1.16	0.31	—	0.10	2.29
0.01	0.01	0.01	0.03	0.19	0.04	0.25	0.31	*	*	0.13	0.03	0.01	0.02	*	0.02	0.10	0.57	0.17	0.04	0.32	0.35	0.10	4.77	9.86
0.07	0.04	0.05	0.05	0.03	0.01	0.42	0.20	0.01	0.04	0.75	0.14	0.37	0.29	0.01	0.09	1.06	2.52	1.01	0.20	1.00	0.05	2.34	26.82	41.66
0.01	0.01	0.01	0.02	0.02	*	0.04	0.33	0.06	0.09	0.06	0.43	0.12	0.07	0.01	—	0.01	0.04	0.08	—	0.04	0.15	—	1.27	3.17
0.02	0.01	0.02	0.05	0.02	0.12	0.30	1.00	*	1.85	0.56	0.02	0.12	0.09	0.03	—	0.07	0.40	—	—	0.14	0.03	—	6.99	12.81
0.02	0.01	0.03	0.05	0.02	0.01	0.15	1.96	0.05	0.21	0.21	0.06	0.71	0.40	0.18	—	0.39	0.08	—	—	—	0.22	0.80	20.29	28.86
0.01	0.05	0.06	0.01	0.02	*	0.03	1.71	0.09	0.14	0.04	0.06	0.12	0.02	0.10	—	0.06	0.13	0.42	—	*	0.04	—	0.18	5.10
*	*	*	0.02	0.11	0.01	0.26	1.42	0.02	0.11	0.03	0.07	0.56	0.08	0.02	0.03	0.23	0.82	1.17	—	—	0.08	0.27	8.35	14.30
—	—	—	—	—	*	*	—	—	0.02	—	—	—	0.09	—	—	—	—	0.16	—	—	5.08	—	8.04	13.39
—	—	—	—	—	—	—	—	—	—	—	—	—	0.01	0.39	—	—	—	0.01	—	0.13	—	—	2.40	2.94
—	*	—	—	—	—	0.04	0.39	0.01	0.11	0.03	0.02	*	*	0.01	—	—	*	0.01	—	0.03	*	—	—	2.13
—	—	—	—	—	—	0.01	—	—	—	—	—	—	0.15	—	—	—	—	—	—	—	—	—	13.11	13.27
0.02	0.01	0.02	0.27	1.12	*	0.13	0.18	0.18	0.03	4.08	*	0.06	0.34	0.02	—	0.07	0.01	—	—	—	5.26	15.70	0.15	28.49
0.34	0.19	0.87	0.25	0.10	0.04	0.03	2.59	0.01	0.71	0.36	0.31	1.13	0.91	0.22	—	0.59	0.43	—	—	—	—	—	—	21.60
0.01	0.05	0.16	*	—	—	—	—	—	—	—	—	—	—	—	0.40	—	—	—	—	0.02	—	—	—	4.43
0.01	0.05	0.14	0.01	0.04	0.50	0.08	—	0.03	0.10	—	—	—	—	*	0.07	—	—	0.01	—	—	1.31	—	1.32	9.52
0.12	0.13	0.19	1.14	0.91	0.26	0.77	3.30	0.44	1.11	4.00	0.21	0.50	0.17	0.32	0.07	1.41	0.47	2.19	0.34	0.83	3.46	0.22	31.55	63.69
1.95	0.90	2.17	5.11	5.70	0.90	6.20	26.42	2.15	7.93	14.06	1.08	8.20	9.41	1.50	—	4.20	10.73	2.27	—	0.85	30.06	—	2.12	223.58
4.00	2.12	4.76	9.21	9.95	2.29	9.86	41.66	3.17	12.81	28.86	5.10	14.30	13.39	2.94	2.13	13.27	28.49	21.60	5.28	17.21	51.29	33.29	194.12	

horizontal row at the top the same breakdown is repeated. When a sector is read horizontally, the numbers indicate what it ships to other sectors. When a sector is read vertically, the numbers show what it consumes from other sectors. The asterisks stand for sums less than $5 million. Totals may not check due to rounding.



INPUT TO AUTO INDUSTRY from other industries per $1,000 of auto production was derived from the 1939 interindustry table. Comparing these figures with those for the auto industry in the 1947 table would show changes in input structure of the industry due to changes in prices and technology.

facts with which it is concerned in every real situation.

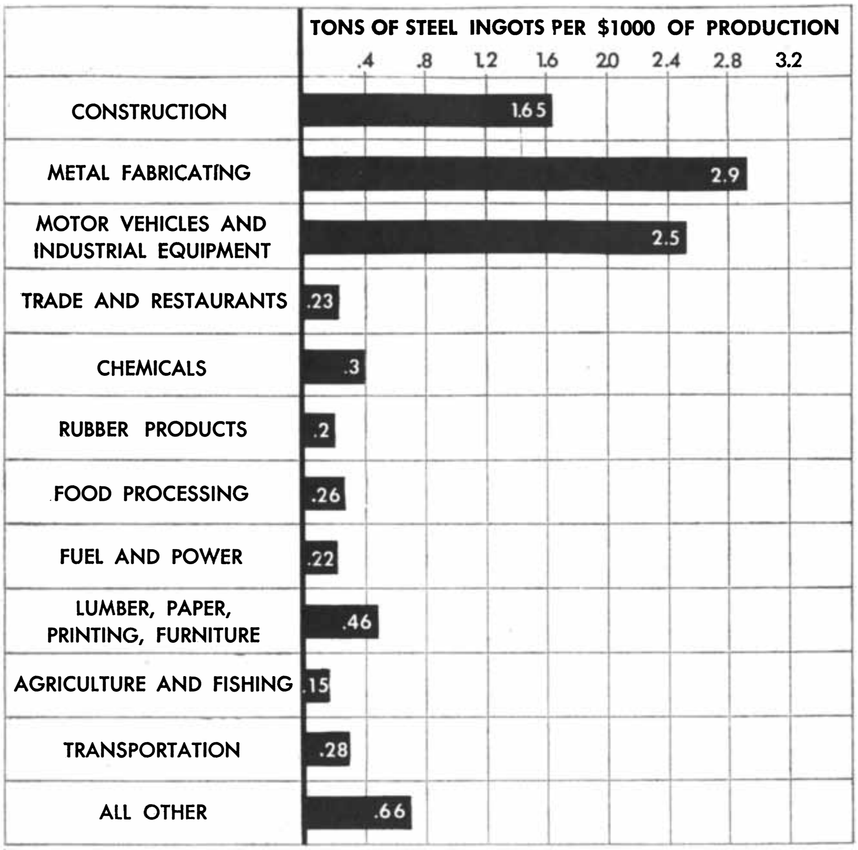
The essential principles of the method may be most easily comprehended by consulting the input-output table on the past two pages. This table summarizes the transactions which characterized the U. S. economy during the year 1947. The transactions are grouped into 42 major departments of production, distribution, transportation and consumption, set up on a matrix of horizontal rows and vertical columns. The horizontal rows of figures show how the output of each sector of the economy is distributed among the others. Conversely, the vertical columns show how each sector obtains from the others its needed inputs of goods and services. Since each figure in any horizontal row is also a figure in a vertical column, the output of each sector is shown to be an input in some other. The double-entry bookkeeping of the input-output table thus reveals the fabric of our economy, woven together by the flow of trade which ultimately links each branch and industry to all others. Such a table may of course be developed in as fine or as coarse detail as the available data permit and the purpose requires. The present table summarizes a much more detailed 500-sector master table which has just been completed after two years of intensive work by the Interindustry Economics Division of the Bureau of Labor Statistics.

FOR purposes of illustration let us look at the input-output structure of a single sector—the one labeled "primary metals" (sector 14). The vertical column states the inputs of each of the various goods and services that are required for the production of metals, and the sum of the figures in this column represents the total outlay of the economy for the year's production. Most of the entries in this column are self-explanatory. Thus it is no surprise to find a substantial figure entered against the item "products of petroleum and coal" (sector 10). The design of the table, however, gives a special meaning to some of the sectors. The outlay for "railroad transportation" (sector 23), for example, covers only the cost of hauling raw materials to the mills; the cost of delivering primary metal products to their markets is borne by the industries purchasing them. Another outlay requiring explanation is entered in the trade sector (sector 26). The figures in this sector represent the cost of distribution, stated in terms of the trade margin. The entries against trade in the primary metals column, therefore, cover the middleman's markup on the industry's purchases; trade margins on the sale of primary metal products are charged against the consuming industries. Taxes paid by the industry are entered in the row labeled "government" (sector 40), and all payments to individuals, including wages, salaries and dividends, are summed up in the row labeled "households" (sector 42). How the output of the metals industry is distributed among the other sectors is shown in row 14. The figures indicate that the industry's principal customers are other industries. "Households" and "government" turn up as direct customers for only a minor portion of the total output, although these two sectors are of course the principal consumers of metals after they have been converted into end products by other industries.

Coming out of the interior of the table to the outer row and columns, the reader may soon recognize many of the familiar total figures by which we are accustomed to visualize the condition of the economy. The total outputs at the end of each industry row, for example, are the figures we use to measure the size or the health of an industry. The gross national product, which is designed to state the total of productive activity and is the most commonly cited index for the economy as a whole, may be derived as the grand total of the five columns grouped under the heading of final demand, but with some adjustments necessary to eliminate the duplication of transactions between the sectors represented by these columns. For example, the total payment to households, at the far right end of row 42, includes salaries paid by government, a figure which duplicates in part the payment of taxes by households included in the total payment to government.

WITH this brief introduction the lay economist is now qualified to turn around and trace his way back into the table via whatever chain of interindustry relationships engages his interest. He will not go far before he finds himself working intuitively with the central concept of input-output analysis. This is the idea that there is a fundamental relationship between the volume of the output of an industry and the size of the inputs going into it. It is obvious, for example, that the purchases of the auto industry (column 18) from the glass industry (row 13) in 1947 were strongly determined by the number of motor vehicles produced that year. Closer inspection will lead to the further realization that every single figure in the chart is dependent upon every other. To take an extreme example, the appropriate series of inputs and outputs will show that the auto industry's purchases of glass are dependent in part upon the demand for motor vehicles arising out of the glass industry's purchases from the fuel industries.

These relationships reflect the structure of our technology. They are expressed in input-output analysis as the ratios or coefficients of each input to the total output of which it becomes a part. A table of such ratios on the opposite page, computed from a table for the economy as of 1939, shows how much had to be purchased from the steel, glass, paint, rubber and other industries to produce $1,000 worth of automobile that year. Since such expenditures are determined by relatively inflexible engineering considerations or by equally inflexible customs and institutional arrangements, these ratios might be used to estimate the demand for materials induced by auto production in other years. With a table of ratios for the economy as a whole, it is possible in turn to calculate the secondary demand on the output of the industries which supply the auto industry's suppliers and so on through successive outputs and inputs until the effect of the final demand for automobiles has been traced to its last reverberation in the farthest corner of the economy. In this fashion input-output analysis should prove useful to the auto industry as a means for dealing with cost and supply problems.



OUTPUT OF STEEL INDUSTRY depends heavily on what kinds of goods are demanded in the ultimate market. This table shows the amount of steel required to meet each $1,000 of the demand for other goods in 1939. The current demand for the top three items is responsible for the steel shortage.

The table of steel consumption ratios on this page suggests, incidentally, how the input-output matrix might be used for the contrasting purpose of market analysis. Since the ultimate markets for steel are ordinarily buried in the cycle of secondary transactions among the metal-fabricating industries, it is useful to learn from this table how many tons of steel at the mill were needed in 1939 to satisfy each thousand dollars worth of demand for the products of industries which ultimately place steel products at the disposal of the consumer. This table shows the impressively high ratio of the demand for steel in the construction and consumer durable-goods industries which led the Bureau of Labor Statistics to declare in 1945 that a flourishing postwar economy would require even more steel than the peak of the war effort. Though some industry spokesmen took a contrary position at that time, steel production recently has been exceeding World War II peaks, and the major steel companies are now engaged in a 16-million-ton expansion program which was started even before the outbreak of the war in Korea and the current rearmament.

The ratios shown in these two tables are largely fixed by technology. Others in the complete matrix of the economy, especially in the trade and services and households sectors, are established by custom and other institutional factors. All, of course, are subject to modification by such forces as progress in technology and changes in public taste. But whether they vary more or less rapidly over the years, these relationships are subject to dependable measurement at any given time.

Here we have our bridge between theory and facts in economics. It is a bridge in a very literal sense. Action at a distance does not happen in economics any more than it does in physics. The effect of an event at any one point is transmitted to the rest of the economy step by step via the chain of transactions that ties the whole system together. A table of ratios for the entire economy gives us, in as much detail as we require, a quantitatively determined picture of the internal structure of the system. This makes it possible to calculate in detail the consequences that result from the introduction into the system of changes suggested by the theoretical or practical problem at hand.

In the case of a particular industry we can easily compute the complete table of its input requirements at any given level of output, provided we know its input ratios. By the same token, with somewhat more involved computation, we can construct synthetically a complete input-output table for the entire economy. We need only a known "bill of final demand" to convert the table of ratios into a table of magnitudes. The 1945 estimate of postwar steel requirements, for example, was incidental to a study of the complete economy based upon a bill of demand which assumed full employment in 1950. This bill of demand was inserted into the total columns of a table of ratios based on the year 1939. By arithmetical procedures the ratios were then translated into dollar figures, among which was the figure for steel, which showed a need for an absolute minimum of 98 million ingot tons. Actual production in 1950, at the limit of capacity, was 96.8 million tons.

THOUGH its application is simple, the construction of an input-output table is a highly complex and laborious operation. The first step, and one that has little appeal to the theoretical imagination, is the gathering and ordering of an immense volume of quantitative information. Given the inevitable lag between the accumulation and collation of data for any given year, the input-output table will always be an historical document. The first input-output tables, prepared by the author and his associates at Harvard University in the early 1930s, were based upon 1919 and 1929 figures. The 1939 table was not completed until 1944. Looking to the future, a table for 1953 which is now under consideration could not be made available until 1957. For practical purposes the original figures in the table must be regarded as a base, subject to refinement and correction in accord with subsequent trends. For example, the 1945 projection of the 1950 economy on the basis of the 1939 table made suitable adjustments in the coal and oil input ratios of the transportation industries on the assumption that the trend from steam to diesel locomotives would continue throughout the period.

The basic information for the table and its continuing revision comes from the Bureau of the Census and other specialized statistical agencies. As the industrial breakdown becomes more detailed, however, engineering and technical information plays a more important part in determining the data. A perfectly good way to determine how much coke is needed to produce a ton of pig iron, in addition to dividing the output of the blast furnace industry into its input of coke, is to ask an ironmaster. In principle there is no reason why the input-output coefficients should not be entirely derived from "below," from engineering data on process design and operating practice. Thus in certain studies of the German economy made by the Bureau of Labor Statistics following World War II the input structures of key industries were set up on the basis of U. S. experience. The model of a disarmed but self-supporting Germany developed in these studies showed a steel requirement of 11 million ingot tons, toward which actual output is now moving. Completely hypothetical input structures, representing industries not now operating, have been introduced into tables of the existing U. S. economy in studies conducted by Air Force economists.

THIS brings us to the problem of computation. Since the production level required of each industry is ultimately dependent upon levels in all others, it is clear that we have a problem involving simultaneous equations. Though the solution of such equations may involve no very high order of mathematics, the sheer labor of computation can be immense. The number of equations to be solved is always equal to the number of sectors into which the system is divided. Depending upon whether a specific or a general solution of the system is desired, the volume of computation will vary as the square or the cube of the number of sectors involved. A typical general solution of a 42-sector table for 1939 required 56 hours on the Harvard Mark II computer. Thanks to this investment in computation, the conversion of any stipulated bill of demand into the various industrial production levels involves nothing more than simple arithmetic. The method cannot be used, however, in the solution of problems which call for changes in the input-output ratios, since each change requires a whole new solution of the matrix. For the larger number of more interesting problems which require such changes, special solutions are the rule. However, even a special solution on a reasonably detailed 200-sector table might require some 200,000 multiplications and a greater number of additions. For this reason it is likely that the typical non-governmental user will be limited to condensed general solutions periodically computed and published by special-purpose groups working in the field. With these the average industrial analyst will be able to enjoy many of the advantages of the large and flexible machinery required for government analyses relating to the entire economy.

A demonstration of input-output analysis applied to a typical economic problem is presented in the table on the opposite page, which shows the price increases that would result from a general 10 per cent increase in the wage scale of industry. Here the value of the matrix distinguishing between direct and indirect effects is of the utmost importance. If wages constituted the only ultimate cost in the economy, a general 10 per cent rise in all money wages would obviously lead to an equal increase in all prices. Since wages are only one cost and since labor costs vary from industry to industry, it can be seen in the chart that a 10 per cent increase in wages would have decidedly different effects upon various parts of the economy. The construction industry shows the greatest upward price change, as it actually did in recent decades. For each industry group the chart separates the direct effect of increases in its own wage bill from the indirect effects of the wage increases in other industries from which it purchases its inputs. Giving effect to both direct and indirect increases, the average increase in the cost of living is shown in the chart to be only 3.7 per cent. The 10 per cent money-wage increase thus yields a 6.3 per cent increase in real wage rates. It should be noted, however, that the economic forces which bring increases in wages tend to bring increases in other costs as well. The advantage of the input-output analysis is that it permits the disentanglement and accurate measurement of the indirect effects. Analyses similar to this one for wages can be carried through for profits, taxes and other ultimate components of prices.

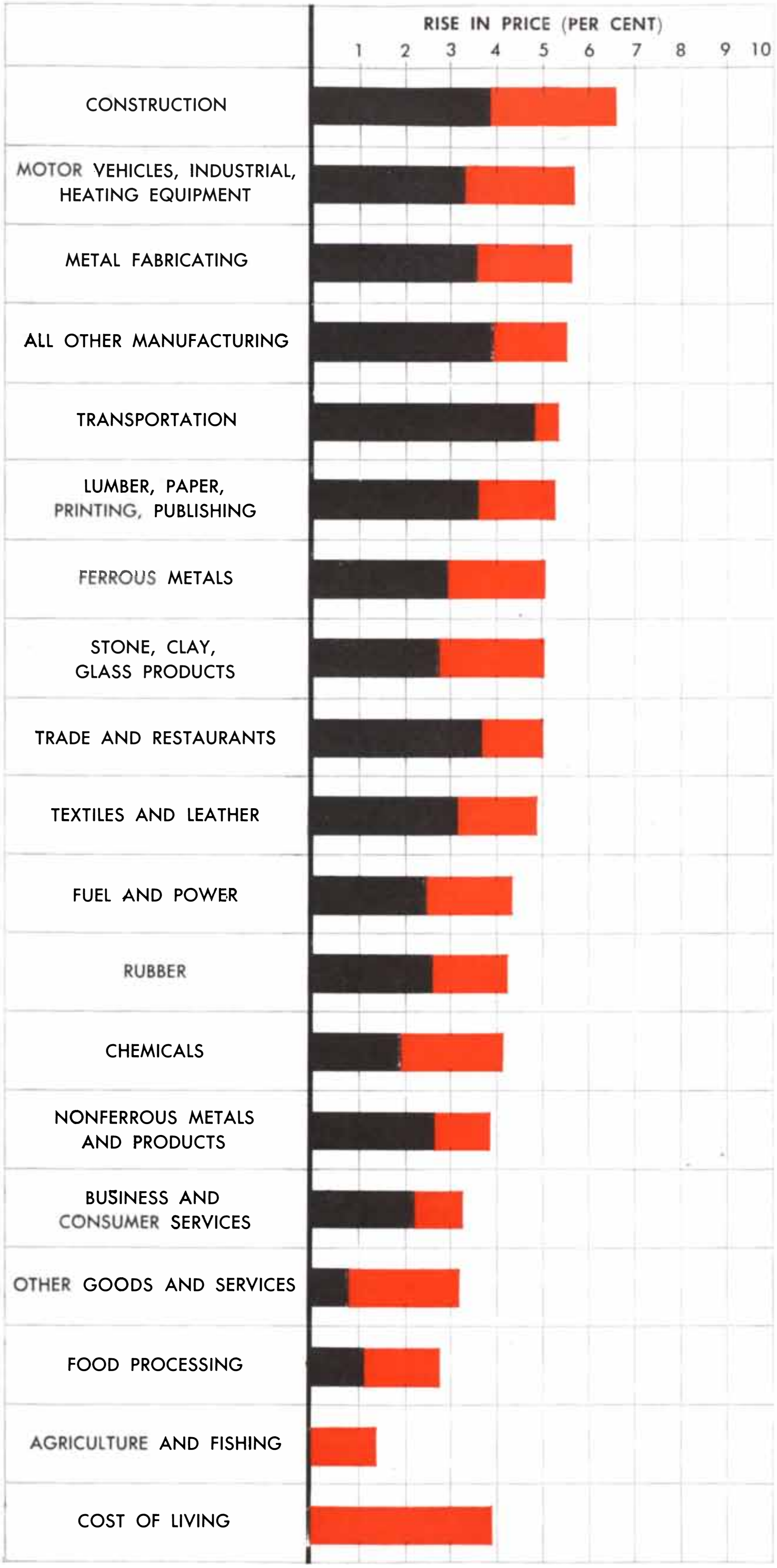
In such examples changes in the economy over periods of time are measured by comparing before and after pictures. Each is a static model, a cross section in time. The next step in input-output analysis is the development of dynamic models of the economy to bring the approximations of the method that much closer to the actual processes of economics. This requires accounting for stocks as well as flows of goods, for inventories of goods in process and in finished form, for capital equipment, buildings and, last but not least, for dwellings and household stocks of durable consumer goods. The dynamic input-output analysis requires more advanced mathematical methods; instead of ordinary linear equations it leads to systems of linear differential equations.

Among the questions the dynamic system should make it possible to answer one could mention the determination of the changing pattern of outputs and inventories or investments and capacities which would attend a given pattern of growth in final demand projected over a five- or ten-year period. Within such broad projections, for example, we would be able to estimate approximately not only how much aluminum should be produced, but how much additional aluminum-producing capacity would be required, and the rate at which such capacity should be installed. The computational task becomes more formidable, but it does not seem to exceed the capacity of the latest electronic computers. Here, as in the case of the static system, the most laborious problem is the assembly of the necessary factual information. However, a complete set of stock or capital ratios, paralleling the flow ratios of all of the productive sectors of the U. S. economy for the year 1939, has now been completed.

This table of capital ratios shows that in addition to the flow of raw pig-iron, scrap, coal, labor and so on, the steel works and rolling mills industry—when operating to full capacity—required $1,800 of fixed investment for each $1,000 worth of output. This would include $336 worth of tools, $331 worth of iron and steel foundry production and so on down to $26 worth of electrical equipment. This means that in order to expand its capacity so as to be able to increase its output by one million dollars worth of finished products annually, the steel works and rolling mills industry would have to install $336,000 worth of tools and spend corresponding amounts on all other types of new fixed installations. This investment demand constitutes of course additional input requirements for the product of the corresponding capital goods industries, input requirements which are automatically taken into account in the solution of an appropriate system of dynamic input-output equations.

ACTIVE experimental work with the dynamic system is under way. Meanwhile the demonstrated power of input-output analysis has thoroughly convinced many workers in the field of its practical possibilities. Of wider consequence is the expectation of theoretical investigators that this new grasp on the facts of the subject will further liberate economics from the confines of its traditionally simplified postulates.

Wassily W. Leontief is professor of economics at Harvard University.



PRICE INCREASES that would be caused by a 10 per cent increase in wages were computed from the 1939 interindustry table. The increases include the direct effect of the rise in each industry's own wage bill (*black bars*) and the indirect effect of price increases on purchases from others (*red*).

THE STATE OF GENETICS

Last summer the geneticists of many lands gathered for a week on Long Island. Their discussions reflected the ferment of a science that is changing both itself and the other provinces of biology

by A. Buzzati-Traverso

IF THE vitality of a science can be measured by the number of facts it brings to light, or by the novelty of its hypotheses, or by the changes in its subject matter, then the science of genetics is extraordinarily vital at present. Two dominant processes are currently at work in this science. On the one hand some earlier genetic findings are being subjected to a more refined analysis; this demonstrates more and more clearly the great complexity of the genetic mechanism, and leads to a reconsideration of older genetic concepts. On the other hand genetic ideas and methods are revolutionizing other biological sciences. These ideas and methods show that the most diverse phenomena which occur in living matter can be regarded as expressions of fundamental processes which are similar throughout the living world. The divisions of biology, such as botany, zoology, bacteriology, embryology and biochemistry, are accordingly breaking down; as a result of genetic investigations we recognize unexpected links among the biological disciplines. Genetics is a kind of cement that joins the many biological phenomena and gives them unity and meaning.

These new trends, these signs of a profound transformation in biology, were much in evidence at a recent scientific meeting. The meeting was the Sixteenth Symposium on Quantitative Biology held by the Long Island Biological Association in Cold Spring Harbor, N. Y., from June 7 to June 15. The title of the meeting was "Genes and Mutations," two words which describe the pivotal elements of biological inheritance. More than 150 biologists, chemists and physicists convened in the congenial environment of the Carnegie Institution at Cold Spring Harbor. Listed in the program were the names of more than 40 of the world's leading geneticists. American, British, Danish, French, Italian, Swedish, Swiss and Yugoslav research workers lived for nine days from early in the morning until late at night in an atmosphere of inquiry and understanding. The result was a series of exciting and fruitful discussions.

What were the themes of the meeting that reflected the state of genetics? What are the most representative and important trends in this science?

The answer is not easy to give, and it will inevitably reflect the personal outlook of the writer. To summarize in a few sentences the discussions at Cold Spring Harbor is almost impossible. The main trends of the meeting can nevertheless be outlined.

GENETICS has been defined as the science that studies heredity and variation. But every phenomenon of biology falls within these limits; each event in the life history of a plant or animal can be explained in terms of inherited traits and their relation to environmental conditions. A horse begets horses and not butterflies because certain physical elements are transmitted from parents to offspring through the germ cells. This fact insures the maintenance of the chief characteristics of the species. But each horse is different from every other horse because the germ cells can also transmit a vast array of different characteristics. These inherited differences maintain the genetic plasticity of the species which is necessary for its survival under different environmental conditions. It is this hereditary variability that is used by man to select races of domestic animals or cultivated plants suited to his needs. Genetics is concerned with the phenomena that underlie such realities. But despite the range of its work, genetics has long been considered a specialized and limited biological subject. How did this impression arise?

For many years geneticists worked hard to get a clear picture of the main laws of inheritance. In this effort they concentrated upon a small number of organisms. To an outside observer it often appeared that the regularities of inheritance observed by geneticists applied in only a few cases, such as the fruit fly *Drosophila,* corn or mice. During this early period of intense investigation geneticists were compelled to coin new words to describe new phenomena; the result was the evolution of a rather specialized language. Other biologists could not make much out of this jargon, and for a time there was a cleavage between genetics and other biological disciplines.

During this period, however, the geneticists made remarkable progress. They found that heredity is controlled by individual particles, composed of proteins and nucleic acids, which are transmitted by both parents to their offspring. Such particles, the genes, do not blend, and do not contaminate one another. The hereditary constituents of the parents can therefore be reassorted in different ways in different individuals at each generation. The genes are located in well-defined bodies, the chromosomes, which lie in the nucleus of every cell in an organism. The genes are arranged in the chromosomes in linear order. Owing to the amazing regularity of the process by which a cell divides into two daughter cells, the chromosomes are also equally divided and distributed. When the sperm and egg cells are formed, and when they are joined, the genes are transmitted and recombined from one generation to the next according to precise quantitative laws. It is these laws that Gregor Mendel discovered in the garden pea around 1860. The geneticists of this century have been able to show that the regularities of inheritance which Mendel discovered are due to the dance of the chromosomes and the genes, a dance that can be observed by the human eye with the help of a microscope. This discovery of the genetic basis of inheritance was the first synthesis of different biological fields. Before that time the study of the cell and the structure of living organisms proceeded along separate and to some extent diverging pathways; the chromosome theory of heredity showed that these apparently unrelated phenomena were due to a common cause related to the process of cell reproduction. The first important step had been made, and the others were bound to follow.

The hypothesis of the linear arrangement of genes within the chromosomes was originally proposed to account for the facts observed in cultures of fruit flies. It was later found to be true for other organisms as well. The basic mechanism of cell division and heredity was found to be common to both animals and plants, and although their structure, function and life history seemed to show more differences than similarities, the transmission of these traits from one generation to the next was found to be the result of the same genetic mechanism.

Once this was established, it was possible to explain the differences among organisms in terms of differences among the genes and their action. Moreover, the stupendous transformations that have occurred in organisms during the course of evolution could be explained by means of transformations of the genes. Finally, if the genes were the fundamental reproducing particles, and were responsible for the development of all the traits exhibited by every organism, then we must regard the gene as the fundamental biological element, as the very basis of life. The extraordinary fact is this: that the ideas presented in these last few sentences are not mere speculations but to a large extent have been proved by experiments.

At Cold Spring Harbor we heard the latest developments in these ideas. Until a short time ago, for example, the chromosome theory of heredity, which had been instrumental in bringing about the scientific unification of plants and animals, did not seem to hold true for the lower organisms such as bacteria and viruses. But the recent genetic attack on the problem of bacterial variation has changed the situation. True inherited variations have been found in bacteria and have proved to be comparable to the mutations found in the genes of higher organisms. Similar results have been obtained in bacteriophages, the viruses which act as parasites of bacteria. At the meeting some startling new discoveries in this field were announced. Edward D. DeLamater of the University of Pennsylvania described convincing evidence for the existence of chromosomes and their regular division in bacteria. He showed clear photographs and microscope slides of cell division in *Bacillus megatherium* which make it possible for the first time to regard bacterial cells as having a structure similar to that of other cells. DeLamater also presented evidence for the existence of fusion processes between bacterial cells; this may prove to be the first microscopic evidence of sexual reproduction in such organisms.

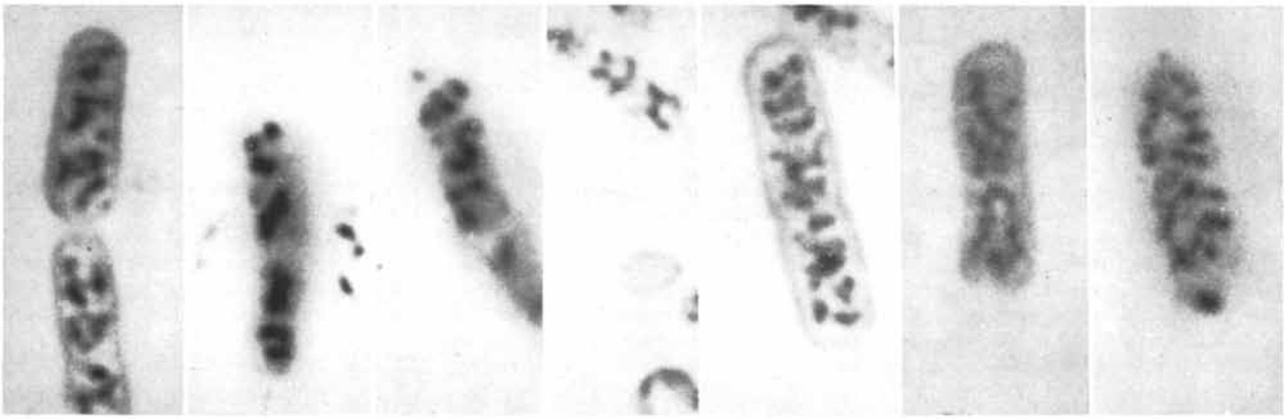
Five years ago Joshua Lederberg of the University of Wisconsin had discovered that bacteria were capable of combining their genes; at Cold Spring Harbor he reported still further evidence of this behavior, and showed how complicated the genetic mechanism of such a common bacterium as the colon bacillus, *Escherichia coli,* can be. Today our genetic understanding of the bacterial cell is in much the same state of change as our knowledge of higher plants and animals was 40 years ago. Then, as now, the evidence for the linear arrangement of genes in the chromosomes was found first by the breeding of experimental organisms, while the visible proof had to wait a number of years. We may well be on the verge of still other developments in this significant field of genetics.

Lederberg also presented evidence for the existence of curious small forms of the bacterium *Salmonella typhi murium.* When passed through a filter that holds back the larger bacteria, these forms retain their genetic individuality. They may well be the first specialized sex cells to be observed in this group of organisms. Although bacterial cells are tiny, the biologist has always hoped that their structure would be revealed by improved techniques; now this structural exploration would seem to have been started by genetics.

On the other hand, bacteriophages are obviously smaller than the bacteria on which they prey; it seems doubtful that we shall ever perceive their chromosomes. In spite of this, these minute organisms certainly possess genetic mechanisms very similar to those in higher forms. At Cold Spring Harbor A. D. Hershey of Washington University showed how it is possible to construct maps which indicate the spatial relationships between several genes in the bacteriophage that disintegrates *Escherichia coli.* S. E. Luria of Indiana University developed a very stimulating hypothesis of how bacteriophages reproduce and mutate. Finally, at a still lower level of genetic organization, Harriett Ephrussi-Taylor of the Institute of Genetics in Paris showed that it is possible to recognize several genetic units within an *extract* of the pneumococcus. The extract contains nucleic acid from one strain of this bacterium; when the extract is added to a culture of another strain, the genetic constitution of the latter is transformed.

So much the same genetic mechanism would seem to be common to all living things; all would appear to share a master plan. This is true of reproducing units so primitive as to lack many characteristics we commonly associate with life, of viruses that lie far below the resolving power of the light microscope, of bacteria that until recently seemed to lack the organized nuclei of other cells, of one-celled animals and plants, and of many-celled organisms including man.

A complete genetic account of life requires that we explain the way genes control the development of the various structural and functional traits of any organism. At Cold Spring Harbor a new light was cast on this area. N. H. Horowitz of the California Institute of Technology and David M. Bonner and Norman H. Giles of Yale University showed how individual genes are responsible for individual biochemical reactions. According to the so-called "one gene-one function" hypothesis it has been surmised that in the course of the development of an organism each gene



CHROMOSOMES OF BACTERIA, which until recently were not known to exist, were exhibited at Cold Spring Harbor by Edward D. DeLamater of the University of Pennsylvania. The bacterium is *Bacillus megatherium;* the chromosomes are the dark bodies within it. The stages shown here run from prophase to interphase.

Szilard, Bonner

Buzzati, Hadorn, Goldschmidt

McClintock, Lindegren

Giles, Kaufmann

serves as a model from which specific kinds of enzyme proteins are copied; these enzyme proteins in turn act as catalyzers or pacemakers of the chemical reactions that take place in the cell. The red bread mold *Neurospora* has provided much precious evidence for the validity of this hypothesis. The Caltech and Yale investigators have analyzed the inherited ability of many strains of this mold to synthesize specific enzymes. Although the one gene-one enzyme relation seems to hold true in some cases, in others it does not; the underlying mechanism would seem to be more complicated than the hypothesis suggests. The interest of such studies, however, goes far beyond the analysis of particular chemical reactions. The genetic approach to the problem of biological synthesis, of how an organism transforms the substances it absorbs from its environment into living matter, has produced a remarkable change in the science of biochemistry. Until a short time ago this science was concerned chiefly with problems of catabolism, of how substances such as sugars or fats or proteins were broken down by the organism. Since biochemistry has become linked with genetics it has become more and more concerned with the problem of anabolism, of synthesis. By this token biochemistry is now closer to the general problems of biology.

THE impact of genetics has been felt not only in other specialized fields of biology but also in the most general biological approach: the study of evolution. After Charles Darwin developed his general theory on the origin of species by means of natural selection, and the biologists and paleontologists of the 19th century provided overwhelming evidence for the occurrence of evolution in past eras, it seemed for some decades that evolutionary studies had come to a dead end. It seemed doubtful that any biologist in one lifetime could prove experimentally the theories that would best interpret the observed evolutionary facts. The process of evolution has required hundreds of millions of years to produce the great variety of living animals and plants; the biologist can only study the changes that occur within his time, at the very most a few decades. But as soon as genetics had formulated the chromosome theory of inheritance, and had shown that hereditary changes are due to mutations in the gene or in the chromosome, a new line of attack on the problem of evolution was disclosed. Evolutionary changes were found to occur within a few generations as the result of the effects of natural selection on a vast array of mutations. This provided a stimulus for the study of mutation itself. The study of mutation by its artificial induction has been an important part of genetics ever since. The occurrence of spontaneous mutations in plant populations was discussed at Cold Spring Harbor by the Swedish geneticist Ake Gustafsson; it was shown that single mutations may have a remarkable evolutionary importance. At the same time, a new approach to the problem of measuring the rate of spontaneous mutation was presented by Aaron Novick and Leo Szilard of the University of Chicago.

The Chicago investigators grow vast populations of bacteria in a new apparatus called the chemostat. In this apparatus it is possible to regulate the rate at which nutrients are fed the bacteria and therefore the rate of their reproduction. By this method it has been shown that the rate of spontaneous mutations is related to astronomical time and not to the number of generations occurring within a period of time. How this may affect our evolutionary theories is not yet clear, because we have no evidence on this point for higher forms of life. However, some experimental evidence presented at the Symposium showed that, contrary to what has been generally believed, an increase in the mutation rate may bring about a more rapid evolutionary change. We now know of several physical and chemical agents capable of increasing the mutation rate in every organism, and several papers presented at the meeting offered new evidence as to how the various agents may act and how different organisms may react to the same agent.

THE genetic attack on biological problems proceeds on an ever-widening front, and it becomes increasingly difficult for the geneticist to keep abreast of new genetic information. This progress is not only quantitative; it is

Horowitz, Atwood, Lederberg

Novick, Rubin

Stadler, Hollaender, Stone

Davis, Demerec

also qualitative. Not only is a wider range of organisms being analyzed in genetic terms, and the genetic background of many different biological phenomena being found, but also the very study of fundamental genetic processes is being pursued at deeper and deeper levels. As in other sciences, the accumulation of new experimental facts makes previous theoretical interpretations obsolete, and new hypotheses are required to account for both the new and the old facts. In genetics we are presently witnessing a very interesting process of refinement of the old fundamental concepts of our science. The experimental evidence now coming from a deeper study of heredity in some of the classical organisms, such as *Drosophila* and corn, as well as to the newcomers to the laboratories of inheritance, such as bacteria and other microorganisms, requires that the geneticist continuously revise his fundamental concepts.

This process of shifting ideas, this change of key, was quite evident in the papers and discussions of the Cold Spring Harbor meeting. The *prima donna* was the gene itself. Originally the gene was conceived as a tiny fraction of the chromosome which controlled a single hereditary trait and had no relation to other genes; it was thought to be in an ivory tower which kept it from promiscuity with other genes and other cell constituents. Although each gene was regarded as a governing center of cell activity, there seemed to be no connection between these numerous centers. Later it was found that one gene could control more than one trait at one time, and that one trait could be affected by more than one gene. Then it was shown that sometimes a gene can change its position within the chromosome and thereby have its function altered. Meanwhile the study of the function of the gene within the cell was being developed, and it was found that the effects of the same gene differ in different cellular environments. Furthermore, the discovery that one can produce mutations with physical and chemical agents showed that the gene, being itself a cellular constituent, cannot be regarded as a completely isolated entity, but that it interacts with other genes as well as with other constituents of the cell.

Now the ivory tower has collapsed, and a more functional picture of the gene emerges. During the early development of genetics the gene was regarded as a material particle that could account for the transmission and reassortment of hereditary traits in successive generations. Then it became the particle in which mutation occurs. Finally it was thought to be the particle that plays a special role in the biochemistry of the cell. This same particle, the gene, was thus being attacked from three different angles: no wonder that the conclusions reached by the three types of attackers sometimes do not fit perfectly with one another. The same thing happens when three climbers approach the summit of a mountain from different sides: although it is the same mountain it may look very different to each climber.

In the introductory lecture of the Symposium Richard B. Goldschmidt of the University of California made the audience feel the difficulties encountered when one tries to interpret some genetic phenomena with the assumption that the genes are discrete particles having no interrelationships with neighboring genes. Barbara McClintock of Cold Spring Harbor and L. J. Stadler of the University of Missouri brought new evidence to the subject from their work with corn. These contributions pointed to the present need of regarding the activity of the gene as a function of the internal organization of the chromosome. The end result is a more elaborate concept of the constitution of the genetic material within the cell nucleus.

Two years from now the Ninth International Congress of Genetics will be held in Italy, and it is safe to make the prediction that many of these present ideas will then look obsolete. As the rate of change in living things can be taken as a good measure of evolutionary progress, the rate of change in ideas can be considered as a sign of health and vitality of a science. The outlook for genetics is good; this science surely promises a rapid evolution in our knowledge of the mechanism of heredity.

A. Buzzati-Traverso is professor of genetics at the University of Pavia in Pavia, Italy.

Synthetic Detergents

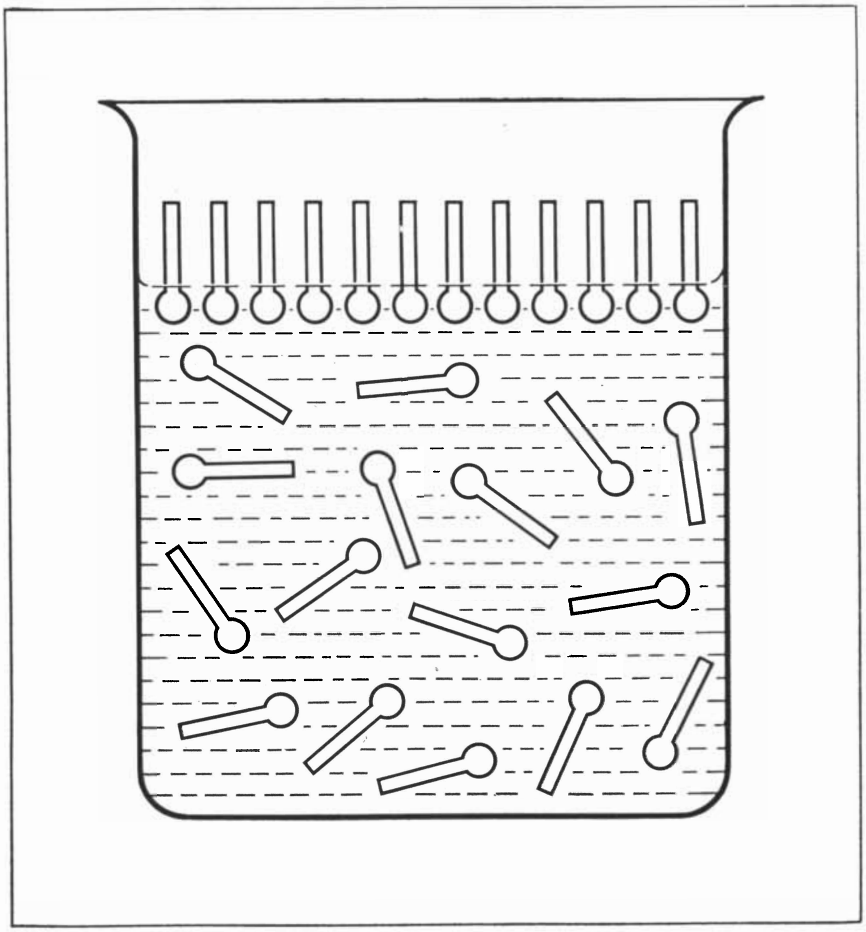
The shortcomings of soap have given rise to a whole new family of cleansing substances. In the U. S. they are now consumed at a rate of a billion pounds a year

by Lawrence M. Kushner and James I. Hoffman

AMONG the most successful developments in chemical technology during the past 20 years have been the synthetic detergents. In 1950 the U. S. consumed approximately a billion pounds of these new cleansing substances. Considering that in the same period the consumption of solid soap, which man has made for at least 2,000 years, was 2.3 billion pounds, this is a striking statistic. And the end is not yet: increasing demand and active research presage an even larger role for synthetic detergents in both household and industry.

We can perceive what lies behind this development by first considering soap and its limitations. Soap is also a detergent, the product of a reaction between animal or vegetable fats and lye. The most useful property of soap is that when we dissolve it in water, the cleansing, or detergent, power of the water is much improved. Until quite recently soap was the only chemically inactive substance that could enhance the cleansing power of water. But soaps have two serious shortcomings. One is that in acid or even neutral solutions soaps are converted into fatty acids. These have no detergent power; indeed, they are insoluble in water. Obviously it is impossible to use soaps in industrial cleansing processes where the presence of acids cannot be avoided. The second shortcoming of soap is that it is very inefficient in parts of the world where the water is "hard." The calcium and magnesium in hard water react with soap to form greasy curds with which we are all too familiar: they are the ring around the bathtub or the dishpan. It is not until all the calcium and magnesium in the water have reacted with a soap that more soap will enable the solution to clean.

The magnitude of this latter problem is sometimes underestimated. Water of average hardness contains the equivalent of only 100 parts of calcium carbonate to a million parts of water. But if we wish to make such water as efficient in cleansing as distilled water, we must use approximately 10 per cent more soap. And the larger part of the U. S. uses water that contains at least 100 parts of calcium or magnesium per million.



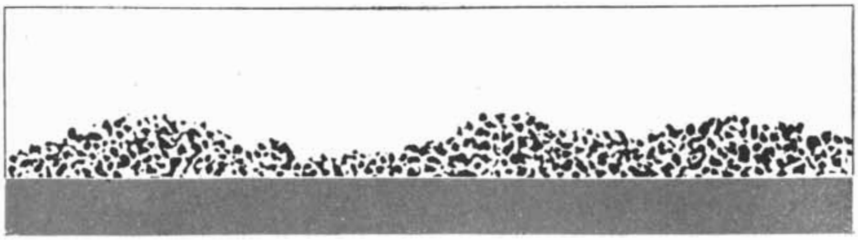
DETERGENT MOLECULES line up on the surface of water because each has a hydrophilic group (*round end*) and a hydrophobic (*rectangular end*).

OUR technology has made two approaches to the inadequacies of soap. The first was the development of water-softening agents that could be incorporated into soap products. The second approach, which is the subject of this article, was the development of entirely new detergent substances. The molecules of these substances were enough like those of soap to have essentially the same cleansing properties, but they differed enough to be immune to the effects of acids or hard water. It is these newly developed substances that we call synthetic detergents.

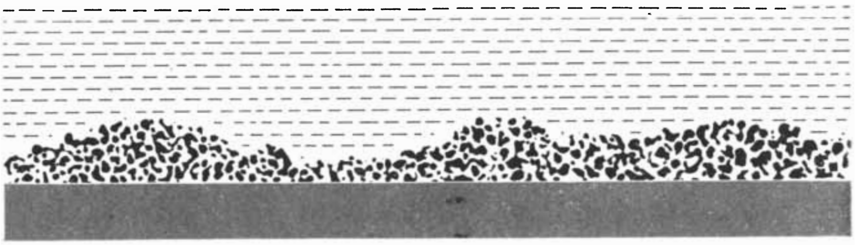
The molecule of a typical soap, sodium laurate, consists of a long chain of hydrogen and carbon atoms ending in a group of carbon, oxygen and sodium atoms; the chemist calls the first part a hydrocarbon and the second a sodium carboxylate group. One of the earliest synthetic detergents, sodium dodecyl sulfate, has a molecule that is strikingly similar. It differs from the molecule of sodium laurate only in the replacement of the sodium carboxylate group by a group composed of sulfur, oxygen and sodium atoms. The similarity does not end there: sodium dodecyl sulfate has a cleansing efficiency comparable to that of soap. Yet its chemical nature is such that it does not react with acids and hard water. Sodium dodecyl sulfate first appeared on the retail market in the late 1930s. World War II then provided an extra stimulus to the development of other synthetic detergents. The fats and oils required for the manufacture of soaps were in short supply; many of the synthetic detergents could be made from the more readily available petroleum products.

The detergents may be divided into three groups: the anionic, the cationic and the non-ionic. The distinction among the three is as follows: When soaps and most of the synthetic detergents are dissolved in water, their molecules split into two electrically charged parts, or ions. In most cases one of the ionic fragments is composed of just one atom; the other fragment is the much larger remainder of the molecule. The two fragments of a given molecule must be oppositely charged. Which of the two will be positive and which negative depends on the structure of the molecule. In the case of the anionic detergents, it is the anion, the negatively-charged group, that is the detergent portion of the molecule. Soap and sodium dodecyl sulfate are anionic. In the case of the cationic detergents, it is the cation, the positively-charged group, that is effective in detergency. The non-ionic detergents do not ionize; their molecules operate as whole, electrically neutral units.

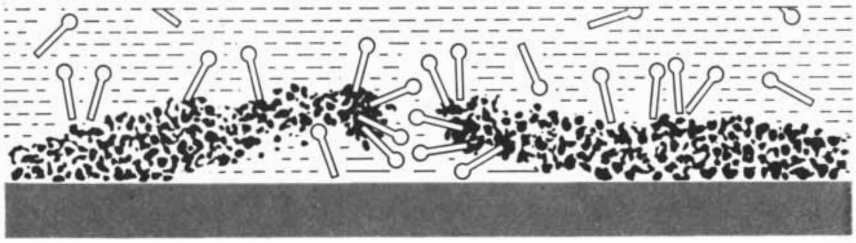
Of the three types of detergents, the anionic is the most widely used. This type performs well, and it may be cheaply produced from readily available raw materials. The present cationic detergents, on the other hand, are too expensive to compete with the anionic for most purposes. But most of the cationics have germicidal properties that make them useful for special applications. The non-ionic detergents are the newest of the three types. They are cheap and have good detergent properties. They are being produced in increasing quantity and should eventually come into competition with the anionics for certain purposes. The big disadvantage of the non-ionics is that they are usually viscous liquids, which for various reasons are not easily marketed. Nonetheless a few are available



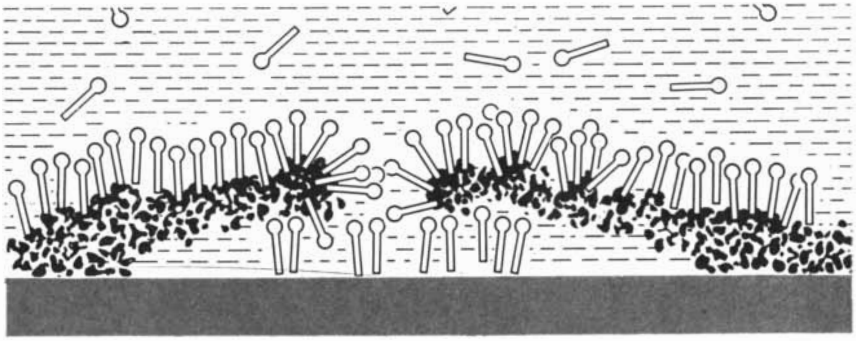
DETERGENT ACTION is depicted in a highly schematic manner by these five diagrams. Here a surface is covered with particles of greasy dirt.



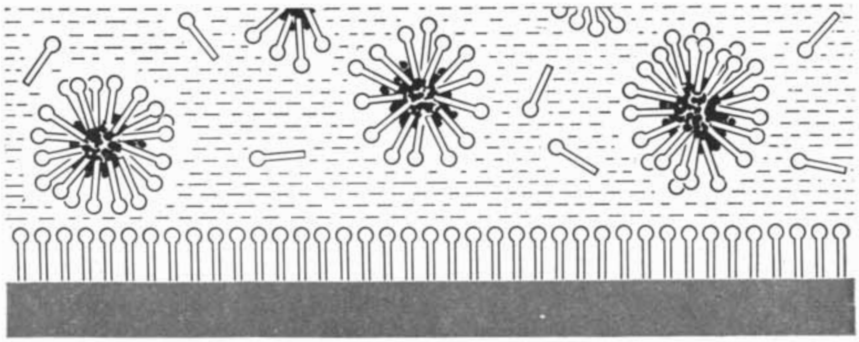
WATER IS ADDED but fails to dislodge the dirt largely because the surface tension of water is too high to permit the most efficient wetting.



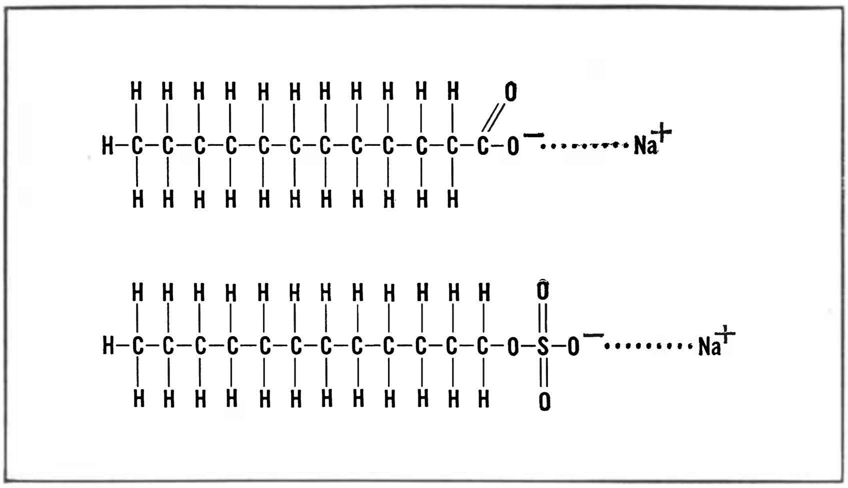
DETERGENT IS ADDED to the water. The hydrophobic ends of the detergent molecules are attracted to the surface between the water and the dirt.



HYDROPHOBIC ENDS of the detergent molecules line up both on the dirt and the surface. The dirt may now be dislodged by mechanical action.



DIRT IS HELD SUSPENDED in the solution because the detergent molecules form a layer on the cleaned surface and surround the dirt particles.



SOAP AND SYNTHETIC DETERGENT molecules are similar. Top: sodium laurate, a soap. Bottom: sodium dodecyl sulfate, a synthetic detergent.

for washing dishes. Much research has recently been devoted to the production of non-ionic detergents as flakes or powder, and in this form they are becoming commercially available. This will surely stimulate the success of these substances.

ALL detergent molecules have a significant feature in common. They are made up of a long hydrocarbon chain which is hydrophobic, or water-hating, and a smaller group of atoms which is hydrophilic, or water-loving. In the anionic detergents, the sodium carboxylate, the sulfur-oxygen-sodium or a similar group is hydrophilic. In the cationics it is the nitrogen-containing part of the molecule that is hydrophilic, and in most non-ionics the part of the molecule that contains oxygen atoms has this property. The hydrophobic-hydrophilic structure is characteristic of all surface active substances. Detergents are only one of these substances; two others are emulsifiers and wetting agents.

Soaps and synthetic detergents owe their cleansing properties to their surface activity in water; we must therefore consider what we mean by surface activity. Both of these substances are soluble in water because they split into ions and/or possess hydrophilic groups. But the long, hydrophobic hydrocarbon portion of a detergent molecule exerts considerable pressure to keep it out of solution. Fortunately there is a compromise which satisfies both the tendency for the hydrophilic portion to dissolve and for the hydrophobic portion to get away from the water. When we dissolve a detergent in water, ions are distributed throughout the solution. However, there is a higher-than-average concentration of large ions at the surface. This excess concentration of ions or molecules at the surface of a solution is called adsorption, and it is the basis for surface activity. The adsorbed ions or molecules are so arranged that their hydrophilic portions are in the water and their hydrophobic portions are out of it.

This marshaling of molecules at the surface of a solution lowers its surface tension, which is a measure of its desire to maintain a minimum surface area. The phenomenon is a result of the fact that the molecules at the surface of a liquid are attracted inward by the other molecules of the liquid much more strongly than they are attracted outward by whatever molecules there are above the surface. It is this inward pull on the surface molecules of free droplets that cause them to assume a spherical shape.

The ions or molecules at the surface of a detergent solution are rather loosely held; indeed, their hydrophobic portions would like to leave the solution entirely. This is another way of saying that the surface tension of the solution is lower than it would be if the detergent were not present. Some precise measurements indicate that the surface tension of detergent solutions is usually less than half that of pure water; the exact value depends on the chemical nature of the detergent. It is this low surface tension that enables detergent solutions to wet a variety of surfaces more thoroughly than plain water does. The willingness of such solutions to have their surfaces extended also accounts for the formation of suds.

As a general rule, it can be said that if the hydrophilic tendencies of a substance overpower the hydrophobic ones, it will be too soluble in water and adsorption at the surface will not occur. Thus the substance will not reduce surface tension. If, on the other hand, the hydrophobic tendencies overpower the hydrophilic, then the substance will probably be insoluble in water. Obviously a surface-active substance is a nice balance between the two opposing tendencies.

Another interesting phenomenon that occurs in detergent solutions is a direct consequence of the hydrophilic-hydrophobic nature of their molecules. If we increase the concentration of a solution beyond the point at which its surface is saturated with detergent ions or molecules, those beneath the surface seek another means of satisfying their hydrophobic tendencies. They combine with each other to form colloidal particles called micelles. Although these particles have been and are being intensively investigated, their exact shape and structure is not known. It is most likely, however, that at relatively low concentrations (.25 to 1 per cent by weight) they are tiny spheres with hydrophilic groups on the surface and hydrophobic groups in the interior. Since the hydrophilic groups normally carry a charge, the surface of the particle will also be charged. The particle will attract a cloud of oppositely charged ions, which will surround it and partially neutralize its surface charge. When the concentration of detergent solutions is higher (about 10 per cent or more) the micelles may take different forms. Many scientific investigators, among them J. W. McBain of Stanford University and W. D. Hawkins of the University of Chicago, have presented evidence for the existence of large, lamellar (*i.e.*, leaf-shaped) or cylindrical micelles under such conditions. Recent work by P. W. Debye and E. W. Anacker of Cornell University also indicates the presence of rod-shaped micelles in certain detergent solutions. But since detergents are customarily used at concentrations of less than one per cent, we probably have only to deal with the smaller spherical micelles.

THE foregoing is a simplified picture of detergent solutions, but it provides us with an adequate basis for an understanding of how detergents work. Household and industrial cleansing almost always involves the removal of greasy dirt from a solid surface, be it a porcelain dish or a textile fabric. The detergent process is generally thought to consist of the following three operations: 1) thorough wetting of the dirt and the surface by the detergent solution; 2) removing the dirt from the surface, and 3) maintaining the dirt in a stable suspension.

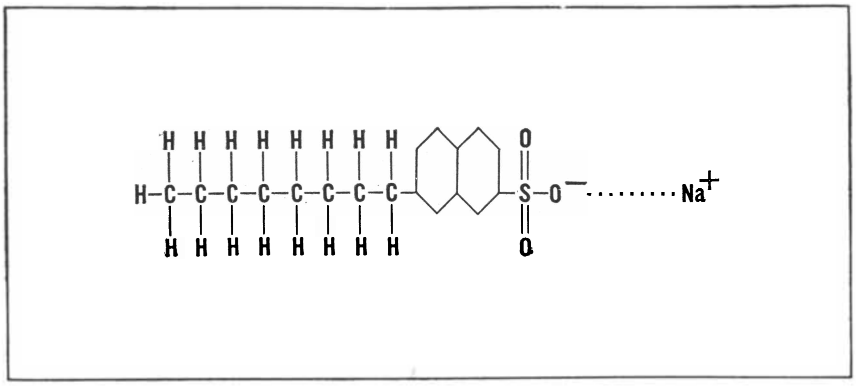
Let us consider the first step, bringing the soiled surface and the detergent solution into intimate contact. Most of us know that if water is poured on an oily surface, it will not spread and wet the surface but will collect into droplets. A detergent solution, however, will completely wet such a surface. A spectacular demonstration of this power of detergents is to put a duck into a detergent solution. The solution so thoroughly displaces air from the animal's naturally oily feathers that its buoyancy is sharply reduced and it must struggle to keep from sinking. Our discussion of detergent solutions indicates why this happens. The molecules at the surface of plain water would much rather be in contact with air or water than with a greasy substance. This keeps the water from spreading on a greasy surface, and results in the formation of droplets which present the least possible area of contact between the water and the grease. The detergent solution, however, has those portions of the detergent molecules at its surface which would rather be in contact with the grease than with the air. Because the hydrophobic portion of the detergent molecule is attracted to the greasy dirt, it acts as a bridge between the dirt and the water. The bridge is joined to the water, of course, by the hydrophilic portion of the molecule. It is by this process that a detergent solution wets a dirty surface.

Next the dirt must be removed. This is most often accomplished by mechanical agitation of one kind or another. The conventional type of washing machine uses a beating or swirling action. Recently there has been much interest in the use of ultrasonic vibrations for this purpose.

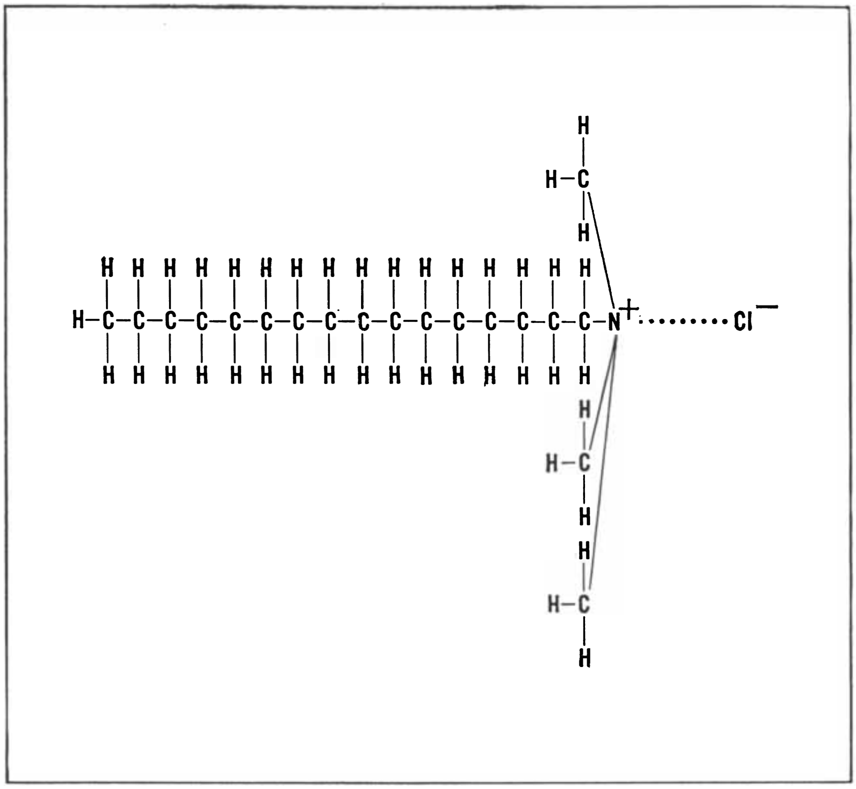
After the dirt has been removed from the surface, it must be suspended in the solution and not allowed to redeposit. The mechanism of the suspension is not completely understood, but it is probably as follows: The ions or molecules of the detergent are adsorbed on the surface between the solution and a particle of greasy material. The hydrophobic portions of the molecules are pointed toward the greasy particle while the charged hydrophilic portions are pointed away from it. The dirt particles are thus covered with a charged layer of detergent molecules. The other particles of dirt in the solution are surrounded by the same charged layer, and since for any given detergent the charge around the particles will have the same sign, the particles mutually repel one another. It is this process that is presumed to keep the dirt from coagulating or settling. Then it is relatively easy to remove the dirt by rinsing.

The great effectiveness of synthetic detergents in suspending dirt is not without its disadvantages. Sewage is often conducted into large basins where the solid particles in it are allowed to settle; now that synthetic detergents are used on a large scale, sanitary engineers have reported that sewage settles more slowly. It appears that concentrations of synthetic detergents as low as a few parts per million will inhibit the settling process.

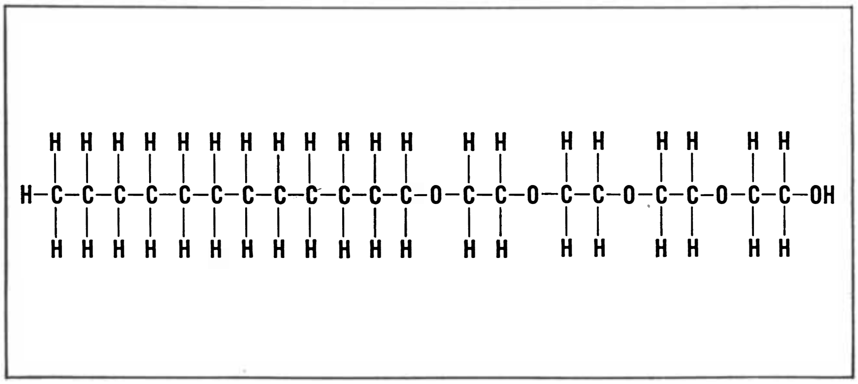
AT the frontier of research in synthetic detergents lie some questions regarding the function of the micelles. It has been shown that substances such as petroleum compounds, the more complex alcohols and the oil-soluble dyes, which are insoluble in water or di-



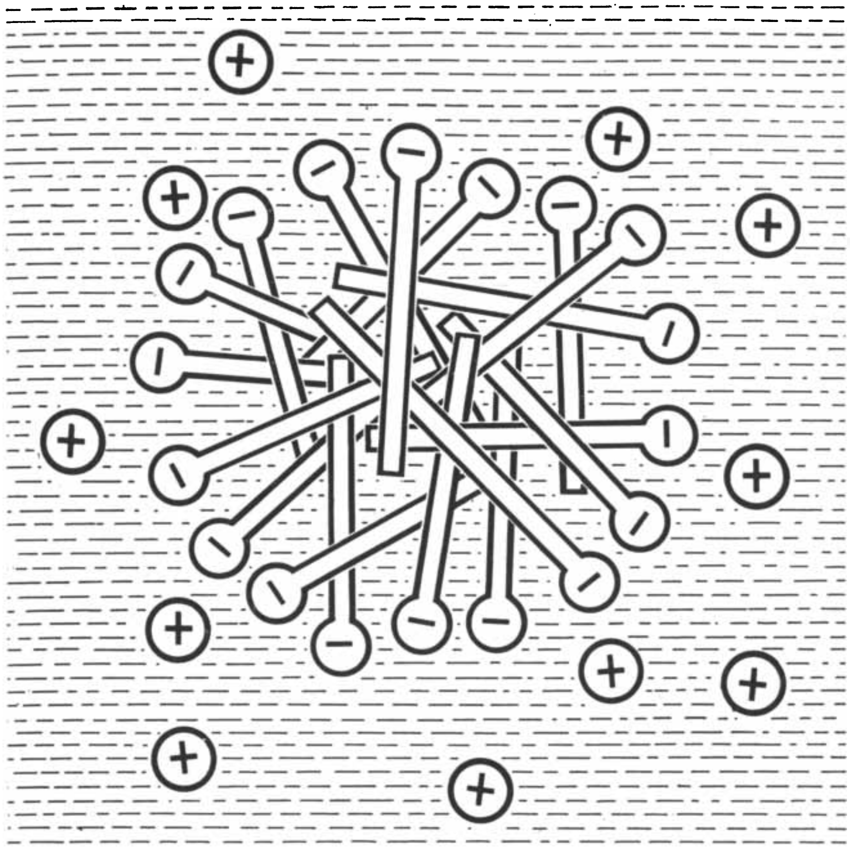
ANIONIC DETERGENT, when ionized (*dotted line*), has a negatively charged larger part. This molecule is sodium octyl naphthalene sulfonate.



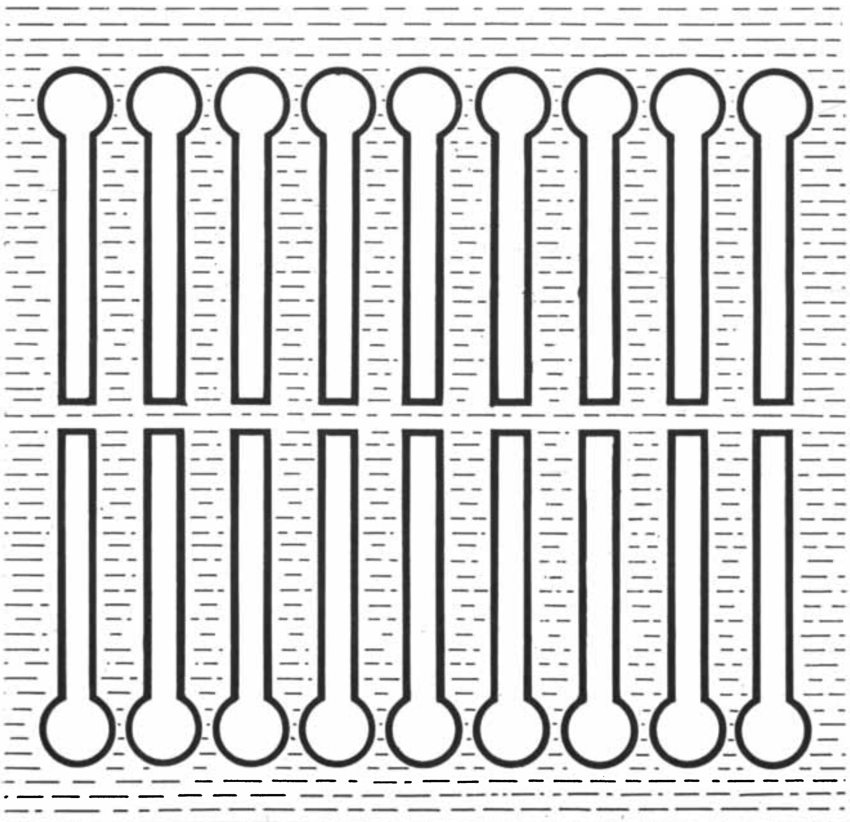
CATIONIC DETERGENT has a positively charged larger part that does the work of detergency. Molecule is hexadecyl trimethyl ammonium chloride.



NON-IONIC DETERGENT does not split into oppositely charged ions at all. This molecule is a condensation product of ethylene oxide and lauryl phenol.



SPHERICAL MICELLES of molecules are formed when a detergent solution reaches a certain concentration. The micelle now attracts positive ions.



LAMELLAR MICELLES, in which detergent molecules form leaflike bodies, may occur when concentration of a detergent solution is higher.

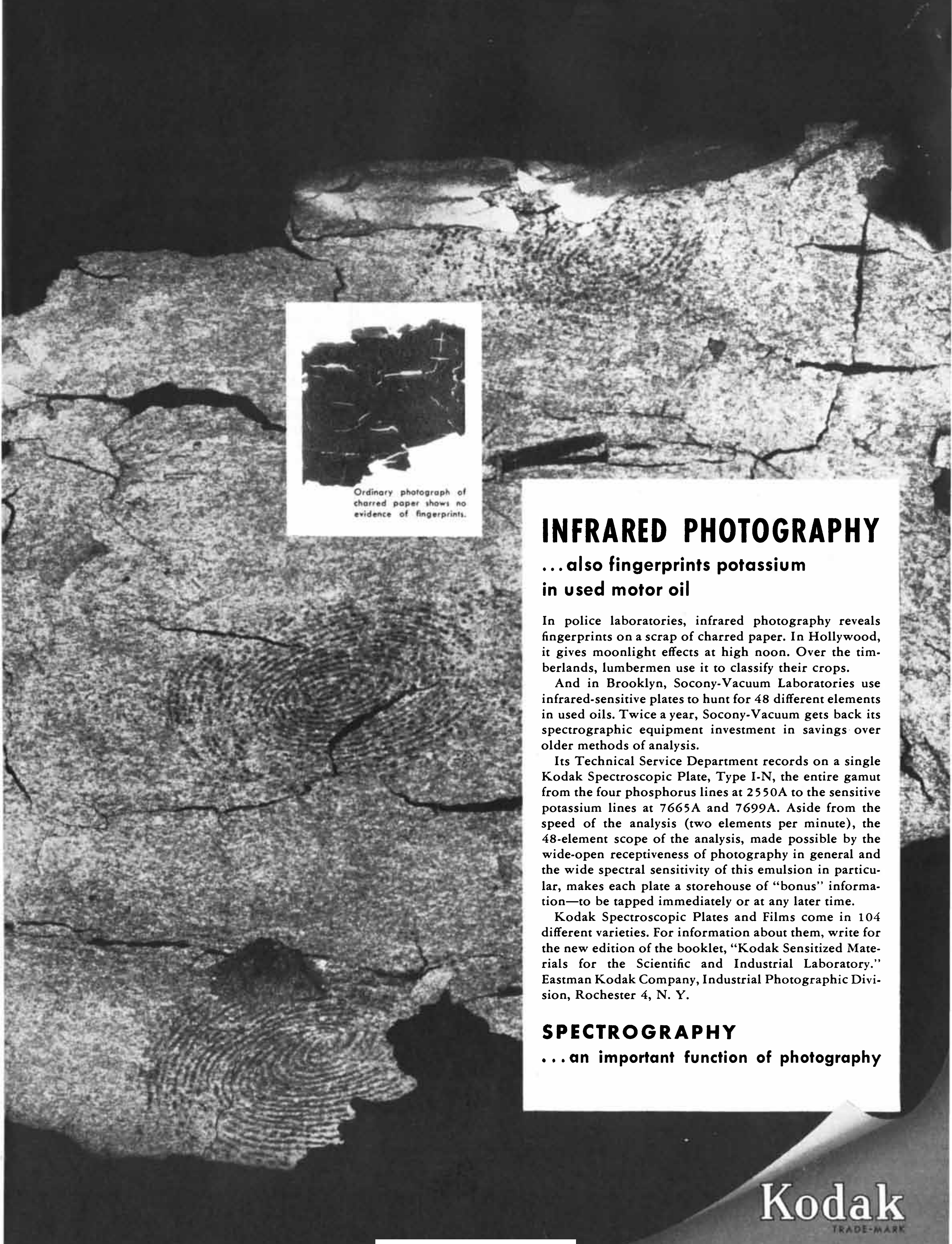
lute detergent solutions, will dissolve in detergent solutions that contain these particles. This process has the rather awkward name of solubilization. Apparently solubilization takes place not in the bulk of a detergent solution but in the hydrocarbon interiors of the micelles. Although this phenomenon is of fundamental interest, it is questionable that it is of primary importance in the detergent process. If we plot the efficiency of a detergent against its concentration, we find that the presence of micelles does not increase the detergent power of the solution. This implies that the primary role of the micelles is as a reservoir of detergent molecules. As detergent is used up by the cleansing process, its concentration is lowered; then the micelles dissociate, freeing more molecules to do their work.

Our present understanding of detergents is fairly recent; it has grown largely as the result of research during the past 30 years. It is this fundamental knowledge that has enabled the development of synthetic detergents to proceed by leaps and bounds. Today there are perhaps 1,000 detergents available on the market. Many of them have been "custom tailored" for a particular application.

Some crystal-gazing on our part leads us to believe that we can look for two particular developments in the future of synthetic detergents. These substances, like soaps, work best in hot water; we can hope that some day they will work just as well in water at room temperature. It is also possible that synthetic detergents will be developed to the point that they can do their work without the help of mechanical agitation, that is to say, that a dirty surface can be cleansed simply by wetting and rinsing it. When we consider the vast scale on which we use detergents in industry and in the home, and the amount of energy that is expended to heat water and agitate it, these advances seem very important indeed. Nor should we overlook such important benefits as the reduction of shrinkage and wear in the many things that we clean.

It is of course possible that the development of synthetic detergents will proceed along different lines. We may, for example, find it desirable, or even necessary, to make our cleansing substances from new raw materials. Be this as it may, we can make one safe prediction. If research in synthetic detergents is pursued with as much vitality in the future as it has been in the past, we are assured of developments in this sector of technology as remarkable as those we have already seen.

Lawrence M. Kushner and James I. Hoffman are chemists at the National Bureau of Standards.



Ordinary photograph of charred paper shows no evidence of fingerprints.

INFRARED PHOTOGRAPHY

...also fingerprints potassium in used motor oil

In police laboratories, infrared photography reveals fingerprints on a scrap of charred paper. In Hollywood, it gives moonlight effects at high noon. Over the timberlands, lumbermen use it to classify their crops.

And in Brooklyn, Socony-Vacuum Laboratories use infrared-sensitive plates to hunt for 48 different elements in used oils. Twice a year, Socony-Vacuum gets back its spectrographic equipment investment in savings over older methods of analysis.

Its Technical Service Department records on a single Kodak Spectroscopic Plate, Type I-N, the entire gamut from the four phosphorus lines at 2550A to the sensitive potassium lines at 7665A and 7699A. Aside from the speed of the analysis (two elements per minute), the 48-element scope of the analysis, made possible by the wide-open receptiveness of photography in general and the wide spectral sensitivity of this emulsion in particular, makes each plate a storehouse of "bonus" information—to be tapped immediately or at any later time.

Kodak Spectroscopic Plates and Films come in 104 different varieties. For information about them, write for the new edition of the booklet, "Kodak Sensitized Materials for the Scientific and Industrial Laboratory." Eastman Kodak Company, Industrial Photographic Division, Rochester 4, N. Y.

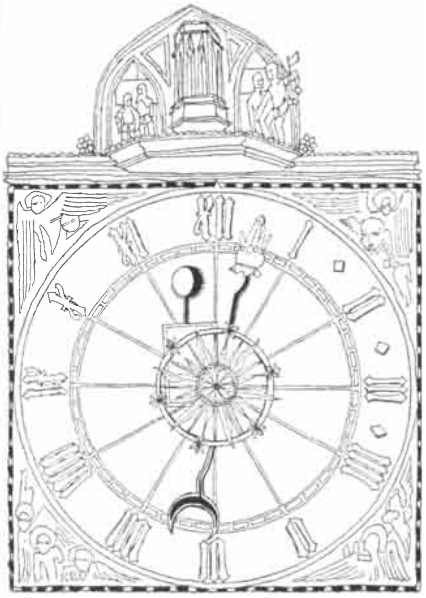
SPECTROGRAPHY

...an important function of photography

Kodak

TRADE-MARK

SCIENCE AND



Fundless Foundation

THE U.S. has a National Science Foundation in principle, but not in fact. Last month the nation's industrial and educational leaders, and the governing Board of the Foundation itself, voiced their deep concern over the continued failure of Congress to permit the Foundation to start the tasks for which it was established. Set up by an Act of Congress a year and a half ago to support research and the training of scientists, the NSF has yet to receive any funds for these activities, and its budget for the coming year again has been cut in Congress to only a token sum. By last month most people were inclined to agree with Charles Allen Thomas, chairman of the board of the American Chemical Society, who remarked reasonably: "It seems obvious that the Congress should support the agency it has created or abolish it."

In its first year the Foundation received an appropriation of $225,000, only enough for administrative expenses. For the coming year its Board proposed a budget of $14 million, of which $5 million was to finance fellowships to train scientists and engineers, $8 million was to be given in grants for basic and applied research and $785,000 was for operating expenses of the Foundation. To the Board's surprise, the House Appropriations Committee cut this budget by 98 per cent, allowing only $300,000. The Committee did not consider the Foundation's work essential: it would not provide "early aid in the present emergency."

As this issue went to press, the nation's scientific and educational organizations were working hard to correct the Congressmen's misapprehension and to salvage the situation in the Senate Appropriations Committee. The chief points they were stressing to Congress were that the nation's serious shortages of scientists and engineers and the "sad neglect" of basic research (*see* Scientific American, September) had made the Foundation's program an imperative emergency need. Said the Foundation Board, which is headed by Harvard University President James B. Conant:

"Failure to provide funds for the operation of the National Science Foundation will have disastrous consequences for the sound future development of our nation, which depends so heavily on science and technology.

"It has been repeatedly emphasized that the nation now faces a critical shortage of men and women adequately trained in science, engineering, public health, medicine and other technical fields. Industry, education and the Government, including the military services, are finding it impossible to fill positions of critical importance to the national defense and the national welfare.

"To meet this urgent need, the NSF has proposed the establishment of a program of fellowships in pure and applied science. Unless funds are provided, this program must be abandoned and the manpower deficit will become increasingly greater."

At the American Chemical Society's huge 75th anniversary meeting in New York the nation's chemists urged that Congress appropriate the full $14 million asked for the NSF. Thomas, speaking for the Society's board of directors, said: "Since no one can tell how long the present emergency will last, the board does not believe support for fundamental research should be denied because there would be no immediate return. If the NSF should be denied the money necessary to carry out an adequate program of fundamental research, and is to receive only enough funds to support an administrative staff, this effectively removes any reason for the existence of the Foundation."

"New and Terrible"

A PROJECT apparently comparable in size to the wartime Manhattan District, for the purpose of developing certain weapons "new and terrible beyond description," is being set up by the Department of Defense, it was indicated last month.

The first public disclosure of the new weapons came from President Truman, who in a speech at San Francisco spoke of non-atomic weapons "now under construction . . . which are utterly fantastic in their operation." A few days later the Senate approved a blank-check appropriation of $5 billion to the Department of Defense. The appropriation was marked simply for expansion of the Army's and Navy's air power, but since it was completely unitemized, it was assumed that the bulk of the money would be for the new weapons. There was no indication as to the nature of the weapons, except that they would be delivered by air in Army and Navy planes. Senator Milton R. Young of North Dakota, a member of the subcommittee that considered the new weapons, said that they were "not atomic but something new and different—more startling than germ warfare."

Chemists

THE largest gathering of chemists ever held took place in New York last month. The 75th anniversary meeting of the American Chemical Society, combined with an international congress of chemists from all over the world, drew some 18,000 scientists and engineers.

At the ACS meeting, which was greeted by President Truman and honored by the issuance of a special commemorative three-cent postage stamp, 700 technical papers were presented. In the principal speech, James Bryant Conant, president of Harvard University, predicted that an atomic war would be avoided. He argued that atomic energy had little promise as a peaceful source of power, and that it would therefore be to the interest of all nations to prohibit any large-scale production of fissionable materials. Conant forecast that within 50 years solar energy would be harnessed and the world would see an era of peace and plenty.

Prizes for achievement in chemistry were awarded to Harrison Brown of the University of Chicago, Gladys A. Emerson of the Merck Institute of Therapeutic Research, Joel H. Hildebrand of the University of California, Yves René Naves of Switzerland, Carrell H. Whitnah of Kansas State College, David M. Bonner of Yale University, Vladimir Haensel of Universal Oil Products Company, Bernard L. Horecker of the National Institutes of Health and Melvin Guy Mellon of Purdue University. E. J. Crane received the Priestley Medal, highest award in U.S. chemistry, for his 37-year editorship of *Chemical Abstracts*.

ACS v. AMA

CHEMICAL and Engineering News, the journal of the American Chemical Society, has accused "a powerful segment" of the medical profession of trying to establish "monopolistic con-

trol" over clinical laboratories in Pennsylvania. The issue is a jurisdictional one; it concerns the question whether chemists may serve as directors of such laboratories.

A bill that would permit them to do so was introduced in the Pennsylvania Legislature. It provided that clinical laboratories, where specimens are tested and analyzed for physicians, might be directed either by M.D.'s qualified in pathology or by scientists experienced in clinical laboratory work. The Pennsylvania State Medical Society fought the bill, insisting that only M.D.'s be approved.

Bitterly denouncing this stand, *Chemical and Engineering News* points out that many of the most highly respected clinical laboratories in the U.S. are directed by chemists who are not M.D.'s. It also asserts that in Pennsylvania a study of 59 analyses made in laboratories directed by doctors showed that "many results were grossly wrong, would mislead the physician in establishing a diagnosis and might affect seriously the treatment and therefore the life of the patient."

Sulfur Bonanza

A HUGE new sulfur deposit found in Louisiana may soon end the severe U.S. sulfur shortage. The deposit is of native crude sulfur or brimstone, the cheapest, most easily processed form of the mineral. It was discovered 100 miles southeast of New Orleans at Garden Island Bay in the marshes of the lower Mississippi River delta. Workers of the Texas Company found it while exploring for oil, which is being produced from the margins of the sulfur formation. The Freeport Sulphur Company has obtained rights to exploit the mineral under a lease that grants the Texas Company half the profits. The Freeport Company plans to build a $10 to $15 million plant. By 1953 the deposit is expected to yield 500,000 long tons annually—enough to close up half of the present million-ton-a-year sulfur deficit. The other 500,000 tons needed will be obtained from other new workings and miscellaneous sources.

Of the total world sulfur supply of 6.5 million long tons per year, used principally for fertilizer, the U.S. normally produces about 90 per cent. Usually its supply is ample. But military production now takes large amounts, and considerable tonnages are being shipped from the U.S. to Great Britain and France for their armament industry.

The Crater in Canada

THE huge crater found in northern Canada less than two years ago was indeed blasted by a meteorite. The geologist V. B. Meen of the Royal Ontario Museum, whose account of the crater's discovery was published recently in this magazine (SCIENTIFIC AMERICAN, May, 1951), returned to the crater site during the past summer and found clear proof that it was of meteoric origin. He identified tons of meteorite fragments scattered around the crater, some of them weighing up to 1,000 pounds. With mine detectors he also located a magnetic anomaly under the eastern rim of the crater, evidently the place where the main mass of the projectile from space is buried.

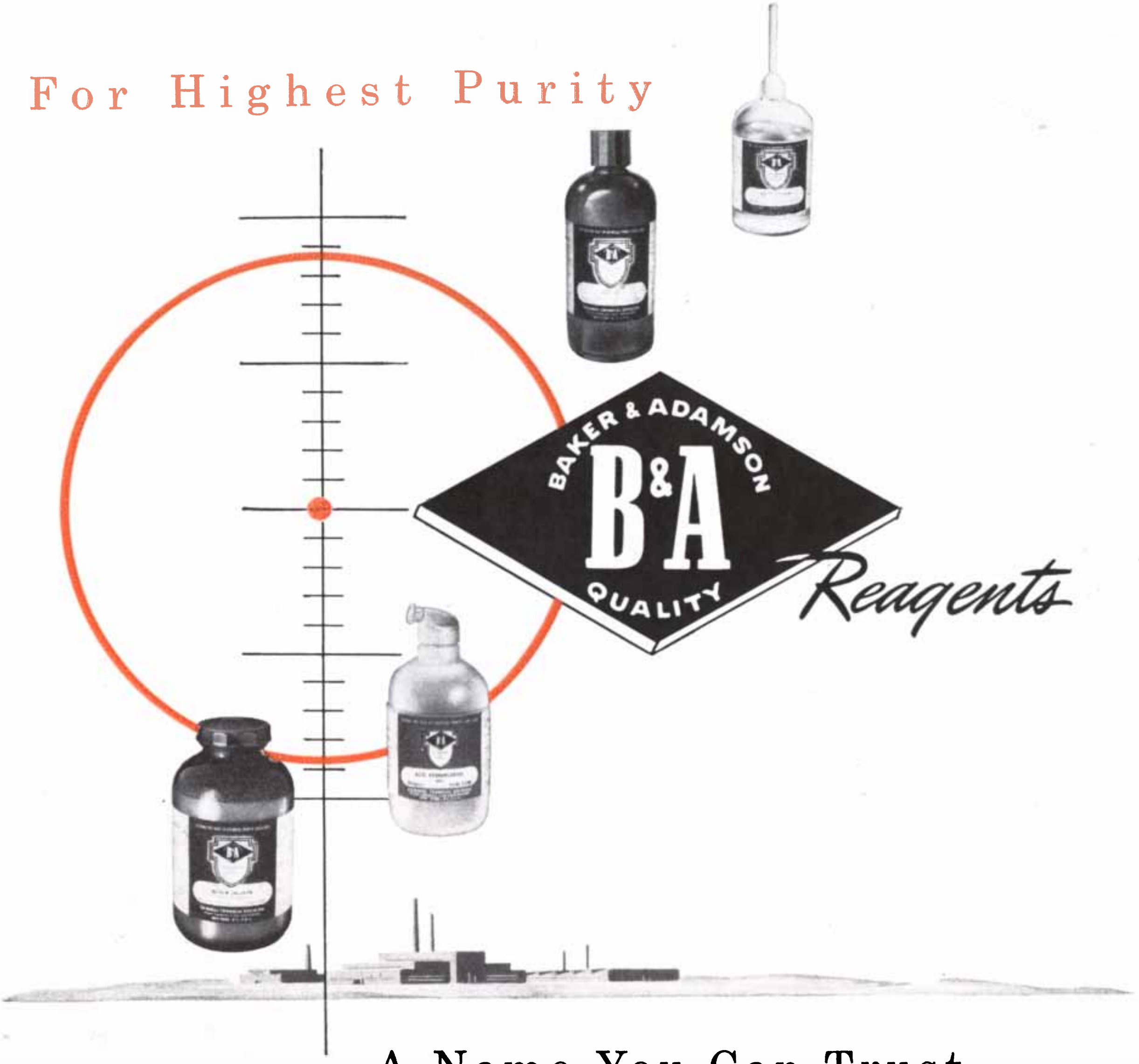
The crater is by far the largest known meteor crater on earth. Meen's expedition determined that the lake-filled excavation is 1,350 feet deep—more than twice as deep as the great Canyon Diablo crater in Arizona.

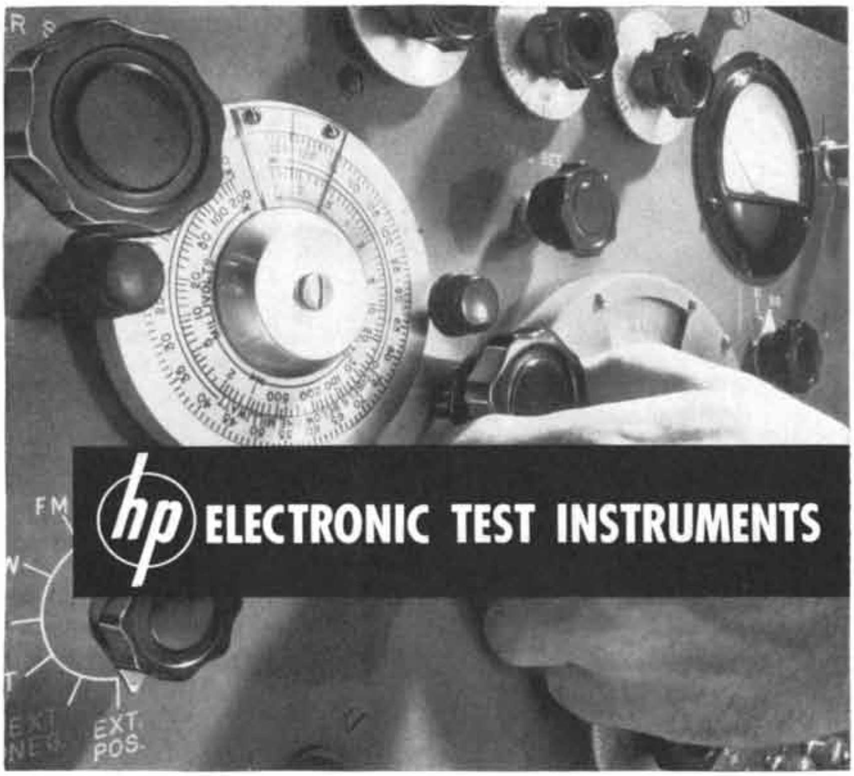
Scrambled Chromosomes

ACCORDING to genetic theory every cell in the body of an animal of a given species should have exactly the same number of chromosomes. The chromosomes are believed to control the heredity of the body cells, assuring, for example, that the arm of a human being will be a human arm. When a fertilized egg divides in two to start the formation of a new offspring, each of the two daughter cells has an identical set of chromosomes, and this process of chromosome reproduction presumably continues as the cells multiply and form the whole animal, so that each body cell has a full set.

This is the theory, but a British geneticist named R. A. Beatty has just called attention to a growing body of evidence that the facts are not in accord with the theory. In recent years cytologists who have taken the trouble to count the chromosomes in body cells have often reported considerable variations in the number, even in the cells of one tissue of an animal. These reports, he says, "have largely been ignored or attributed to faulty methods or faulty observation." Within the past year, however, they have been confirmed by several investigators. Beatty, who works at the Edinburgh University Genetics Laboratory, summarized their findings recently at a meeting of the British Association for the Advancement of Science.

Two Finnish cytologists, S. Timonen and E. Therman of Helsinki, counted the chromosomes in various tissues of human beings. The expected chromosome number in human cells is 48. The Finns found, however, that in the cells they examined the number of chromosomes actually varied from four to 104, and the average number was only about half of the predicted 48. A Russian investigator named Sorokina made a similar count in the cells of pigs. The pig is supposed to have 40 chromosomes in each cell, but Sorokina reported that the number actually ranged from 15 to 69. Similar variations were found in investi-


For Highest Purity
BAKER & ADAMSON
B&A
QUALITY
Reagents



gations of five other species of mammals by other workers.

Beatty took note that some of these reports came from Soviet biologists, who dispute the gene theory, but he pointed out that the Finns had found a wider variation from theoretical predictions than the Russians.

The British geneticist ventured a couple of possible explanations of the chromosome-counters' findings. One suggestion was that the chromosomes may exert their influence on the heredity of cells only during the course of embryonic development (*i.e.*, while the cells are dividing), and that the chromosomes may later become unevenly distributed in the mature cells without affecting the cells' heredity. A second possibility, he suggested, is that whatever the distribution in the individual cells, the body as a whole "contains a very large number of complete chromosome sets, and the fact that they are parceled out unevenly between the different cells does not affect their functioning as complete sets."

Malaria Cure?

THE U.S. Army Medical Service thinks it may have found the first drug that offers a permanent cure for malaria. The trouble with all previous treatments, including quinine, atabrine and chloroquine, has been that while they can destroy the malaria parasite while it is in the bloodstream (the clinical phase of the disease), none can get at it during the quiescent phase when it hides out in the tissues of the liver and other organs.

The new drug, primaquine, appears to be able to reach into the tissue cells to kill the parasite. Originally tried on prisoner volunteers in an Illinois penitentiary, it gave a high percentage of cures with no relapses. The Army then tried it at several hospitals, with favorable results so far, though it is too soon to be sure the cures are permanent. The drug is to receive a large-scale test on several hundred malarial veterans returning from Korea.

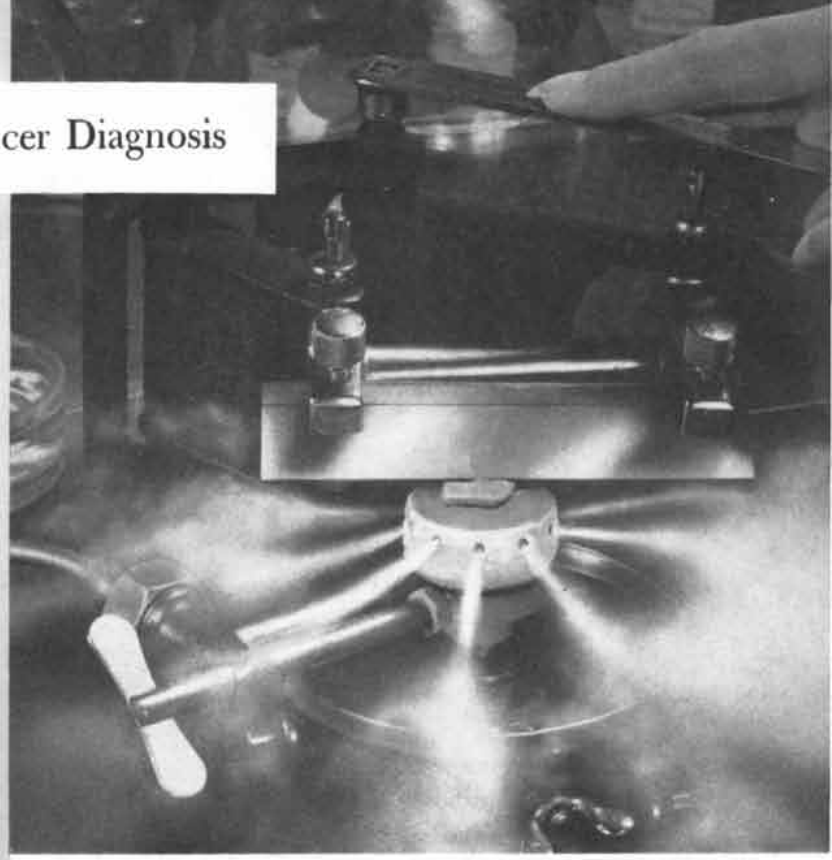
The Army doctors suggest that primaquine may be used in combination with chloroquine to rid the body of parasites at one blow, killing those in the bloodstream and in the tissues.

Blood Union

PHYSICIANS at the University of California School of Medicine have succeeded in linking the arteries of two different individuals so that their blood systems function as one. Although the work is still experimental, the doctors suggest that if their cross-circulation method can be reduced to a standardized clinical procedure, it may have many medical applications.

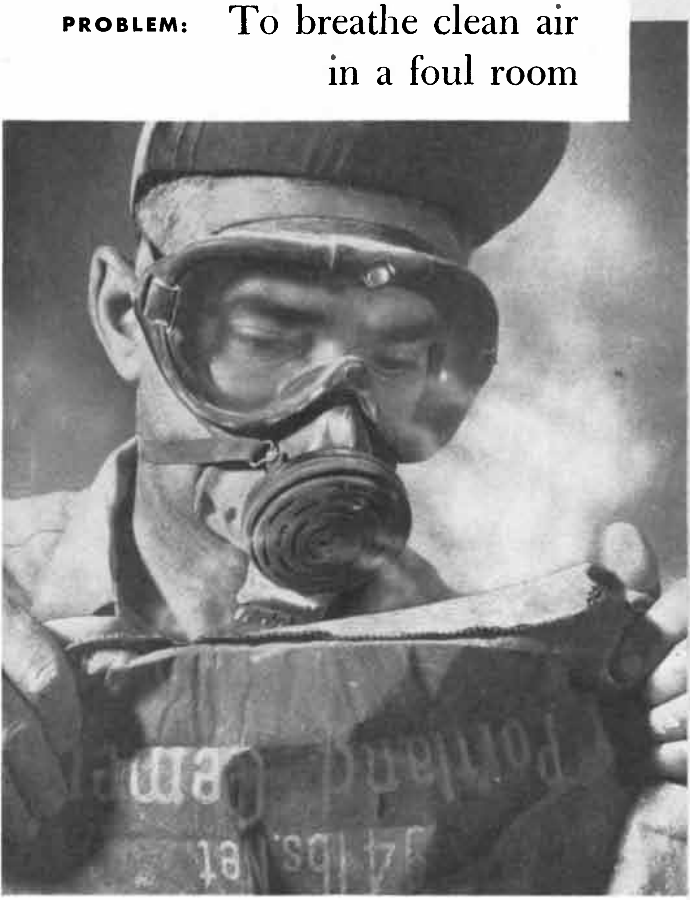
Cross-transfusion has long been used

PROBLEM: Cancer Diagnosis



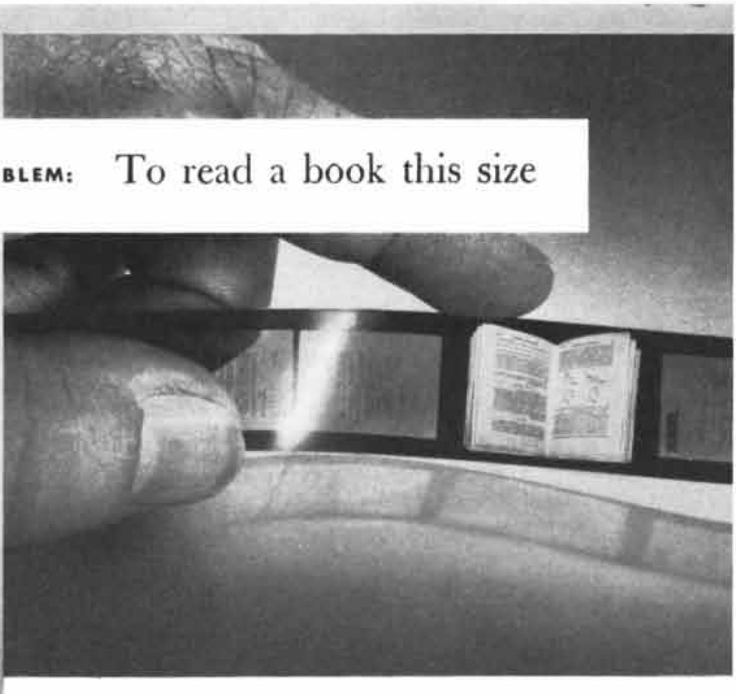
ANSWER: Is it cancer or not? While the patient lies on the operating table, pathologists can look at a microscopic slice of human cell tissue and find out. First, the tissue is frozen by carbon dioxide gas, then is sliced by a *microtome* to an incredible thinness of 12 microns (.00048 inch). Once the finest microtomes came from Europe. American Optical has long since equaled and passed their precision.

PROBLEM: To breathe clean air in a foul room



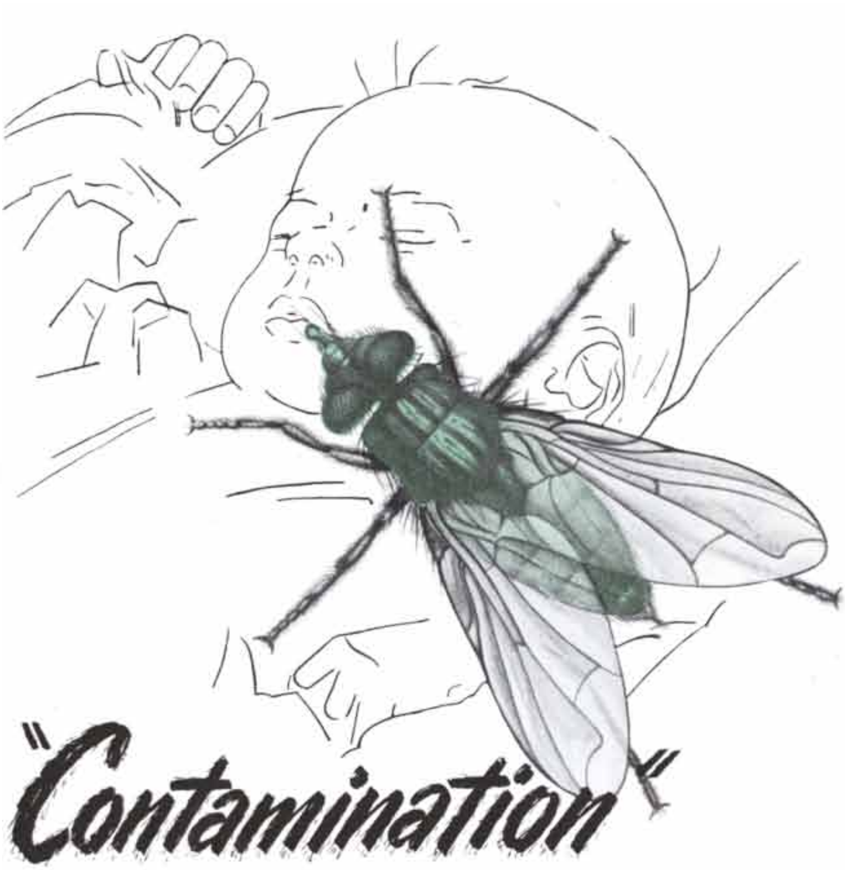
ANSWER: Trapping dusts as small as 24 millionths of an inch in diameter is now possible by American Optical's revolutionary new respirator filter. This chemically treated filter has 40 times the efficiency of similar untreated filters, does work of filters 8 times as large, yet is no harder to breathe through.

PROBLEM: To read a book this size



ANSWER: Books and records, too valuable to lose, are now copied on tiny film, saving time, shelf space, money. American Optical's microfilm "reader" enlarges to natural size and clearly projects the microfilm. These flat, undistorted projected images may be read comfortably for hours. Write us about your development problems. Address American Optical Company, 13 Vision Park, Southbridge, Mass.

American Optical



in experiments on animals, but generally the link has been between the veins rather than the arteries, and a mechanical pump has been required to drive the blood. In the improved new method the heart of the healthy partner provides sufficient power to pump the blood into the circulation of the patient. The California workers have already established such cross-circulation in seven cases, maintaining it for as long as 26 hours. They have been using the technique for research on leukemia.

One of the potential applications, they suggest, is to permit operations on the heart: while the surgeon operates on the organ, a partner's heart will pump blood through the patient's body. Such a cross-transfusion may also make it possible to rest a patient's overburdened liver or kidney. It may be used to treat patients whose blood balance has been impaired by heavy doses of radiation or to supply antibodies to those stricken with such diseases as poliomyelitis.

Volcanic Electricity

THE United Nations Technical Assistance Administration is studying the possibility of harnessing the power in volcanoes more widely as a source of electricity. Its investigations are being carried out on the British West Indies island of St. Lucia, where a great deal of underground volcanic steam escapes through "fumaroles," or openings in the earth.

In Iceland volcanic water and steam are used both for electric power and directly to heat houses, baths and swimming pools. In the Lardarello Valley of Italy live steam from fumaroles for many years has driven turbines and generated electric power. Dissolved minerals are recovered from the steam; the Lardarello plant is the major European source of boric acid. St. Lucia has hopes of getting sulfur as well as power out of its fumaroles.

The tapping of this source of energy sometimes requires drilling wells to reach the live steam. In Italy last year a new well tapped a gusher of steam (at 400 degrees Fahrenheit) which burst forth in an explosion that threw red-hot rocks high into the air and was said to have been heard 15 miles away.

Peyote

IN the Indian country of the Southwest certain tribes make a religious ceremony of eating the curious narcotic peyote. The drug comes from a small spineless cactus that grows in the Rio Grande valley; natives cut off the button-shaped top of the plant, sun-dry it and take it as a pill or in tea. It induces visions, and the members of the Native American Church, an 80-year-old religious sect which has adapted Christi-

TO FORWARD-LOOKING ENGINEERS:

Lockheed in California

OFFERS YOU A BETTER JOB... now and in the future

There's more to a job at Lockheed than eight hours' work a day. There's the friendly spirit of progress—of getting things done—that makes work so much more stimulating. There's the better life you live, just because you live in Southern California.
There's the future that offers you and your family security and advancement with the *leader in aviation.*

New ideas that feed the long-range design program spring from spontaneous conferences such as these.

Better Working Conditions

On the job, you work in an atmosphere of vigorous, progessive thinking. Personal initiative, new ideas are encouraged. Frequent conferences iron out problems, keep work rolling smoothly. You work with top men in your profession—as a member of the team known for leadership.

Outdoor life prevails in Southern California the year around .

Better Living Conditions

Every day, you get a "bonus" at Lockheed—in the better living conditions. The climate is beyond compare. Recreational opportunities are unlimited. Golf, fishing, the patio life at home can be yours 12 months a year. And your high Lockheed salary enables you to take full advantage of the climate and recreational opportunities.

Special training courses prepare you for promotion.

Better future

You have a *future* at Lockheed—not just a job. For Lockheed is building planes for defense, planes for the world's airlines. The planes of tomorrow are being designed today in Lockheed's long-range development program.

Special training courses in management and various phases of aeronautical engineering help prepare you for the future and promotion.

Ask any of the 5,000 who wear 10-year pins whether or not there's a career and security at Lockheed.

Engineering Openings:

Aerodynamicists
Aerodynamics Engineers
Aircraft Design Engineers
Aircraft Electrical and Radio Designers
Airplane Specifications Engineers
Design Engineers
  Lockheed will train you to be an aircraft engineer. Full pay·while training.
Drawing Checkers
Electronics Engineers
Engineering Technical Writers
Flight Manuals Engineers
Machine and Equipment Design Engineers
Manufacturing Engineers
Manufacturing Research Engineers
Production Design Engineers
Senior Electronics Systems Engineers. M.S. or Ph.D. in Electrical Engineering or Physics
Stress Engineers and Analysts
Tool Standards Engineers
Weight Engineers

Also...

Technical Editor
  to write and review technical reports
Sales Engineer
  with airline experience

Send today for free illustrated brochure describing life and work at Lockheed in Southern California. Use handy coupon below:

To Engineers with Families:

Housing conditions are excellent in beautiful San Fernando Valley—the home of Lockheed. Approximately 30,000 rental units are available in the Los Angeles area. Huge tracts are under construction now. Thousands of homes have been built since the last war. Lockheed counselors help you to get settled. Educational facilities also are excellent. The school system offers your children as fine an education as can be obtained anywhere. Elementary and high schools are conveniently located. Junior colleges and major universities abound—21 are in the Los Angeles area.

Lockheed also offers you:

Generous Travel allowances • Outstanding Retirement Plan • Vacations with pay • Low cost group life, health, accident Insurance • Sick Leave with pay • Credit Union, for savings and low-cost financing • Employees' Recreation Clubs • Regular performance reviews, to give you every opportunity for promotion • On-the-job training or special courses of instruction when needed.

Mr. M. V. Mattson, Employment Manager, Dept. SC 10
LOCKHEED Aircraft Corporation
Burbank, California

Please send me your brochure describing life and work at Lockheed.

My Name ____________________

My Street Address ____________________

My City and State ____________________

anity to Indian traditions, eat it as an aid to prayer and contemplation during their periodic night-long ceremonies of worship.

The Federal government and many states are currently conducting vigorous campaigns and passing laws against narcotics. Disturbed about the possible consequences for the Native American Church, five anthropologists who have lived with these Indians and eaten peyote pleaded recently that the church members be allowed their drug. To make it illegal would be to abridge the Indians' religious freedom, they said. Besides, added the anthropologists, the drug does no harm. The five—Sol Tax and J. S. Slotkin of the University of Chicago, Weston La Barre of Duke University, David P. McAllester of Wesleyan University and Omer C. Stewart of the University of Colorado—testified that peyote (1) is not habit-forming, (2) does not result in mental disorganization, (3) causes no orgies among the Indians, and (4) contrary to allegations by enemies of the Native American Church, neither excites nor stupefies.

Dangerous Sport

WHAT is the most dangerous competitive sport? Most people would probably nominate boxing and football, in that order. Now comes a statistical study which purports to show that the most dangerous sport is neither of these but our supposedly innocuous national game—baseball. Thomas A. Gonzales of the New York City Chief Medical Examiner's Office asserts that in that city at least baseball is the deadliest game, according to the cold records.

Dr. Gonzales compiled a box score of fatal injuries in sports during the 32-year period between 1918 and 1950. He found that baseball caused as many deaths as football and boxing combined. The score: baseball 43, football 22, boxing 21, basketball 7, handball 3, soccer 2, wrestling 2, cricket 1, golf 1, polo 1, track 1. Strangely missing was the notoriously murderous game of lacrosse. (Dr. Gonzales excluded non-competitive sports such as mountain climbing, skiing, swimming, hunting and fishing.)

The New York physician, who reported his findings in *The Journal of the American Medical Association*, feels that boxing has an undeserved bad name; noting that it has produced fewer deaths in proportion to the number of participants than baseball or football, he argues that its "moral and physical benefits far outweigh its dangers."

Baseball appears to be reasonably safe for professionals; in the 32 years only one professional ballplayer was killed in New York. But for the amateurs it is somewhat hazardous. Most of the deaths were caused by a thrown or hit ball; 25 of the 43 fatalities were due to a fractured skull.

more lollipops ...and better

because of **ALCOA**

Activated* Alumina

SUCCESSFUL candy manufacturers have discovered they can make more—and better—candy because of ALCOA *Activated* Alumina. This commercially pure, highly inert adsorbent eliminates costly moisture problems—sticky materials, gummed-up machinery, deteriorated products—by continually maintaining the low, even humidity required in processing, hardening and packaging rooms.

ALCOA *Activated* Alumina is a highly efficient and economical desiccant. With it, dew points as low as *minus* 100° F. —and even lower—can be maintained. Moreover, it will not swell, soften or disintegrate even when immersed in water . . . has high resistance to shock and abrasion . . . is non-toxic . . . non-corrosive . . . virtually iron-free.

Because of these outstanding properties, food, candy and drug manufacturers all over the country rely on ALCOA *Activated* Alumina to maintain their production *regardless of the weather*. Chemical, petroleum, air conditioning and oil maintenance men have found it equally effective in their businesses. Perhaps it can simplify *your* processes, speed up *your* production, improve the quality of *your* product. Let us tell you how.

Write to: ALUMINUM COMPANY OF AMERICA, CHEMICALS DIVISION, 629K Gulf Building, Pittsburgh 19, Pennsylvania.

**Reg. T. M., Aluminum Co. of America*

Alcoa Chemicals

ALCOA ALUMINUM ®

ALUMINAS and FLUORIDES

ACTIVATED ALUMINAS • CALCINED ALUMINAS • HYDRATED ALUMINAS • TABULAR ALUMINAS • LOW SODA ALUMINAS
ALUMINUM FLUORIDE • SODIUM FLUORIDE • SODIUM ACID FLUORIDE • FLUOBORIC ACID • CRYOLITE • GALLIUM

© 1951 SCIENTIFIC AMERICAN, INC

DIRK WESSELS VAN LEYDEN
General Manager • AA *Argentine*

C. R. SMITH, President
AMERICAN *U. S.*

CAPT. A. A. BARLOW, General Manager
BCPA *Australian, New Zealand*

T. E. BRANIFF, President
BRANIFF *U. S.*

The airlines these men direct are a vital part of

THE WORLD'S GREATEST

T. C. DRINKWATER, President
WESTERN *U. S.*

Today the 19 men pictured here operate airlines that comprise the world's largest airlift—serving free people everywhere.

Depend on **DOUGLAS**

WORLD'S LARGEST BUILDER OF MILITARY AND COMMERCIAL AIRCRAFT FOR 30 YEARS ➤ MILITARY AND COMMERCIAL TRANSPORTS ➤ FIGHTERS ATTACK PLANES ➤ BOMBERS ➤ GUIDED MISSILES ➤ ELECTRONIC EQUIPMENT ➤ RESEARCH

W. A. PATTERSON, President
UNITED *U. S.*

COL. P. GENAIN, Director General
TAI *French*

DR. W. BERCHTOLD, President
SWISSAIR *Swiss*

THOMAS L. GRACE, President
SLICK *U. S.*

LIC. AARON SAENZ, President
CMA *Mexican*

C. E. WOOLMAN, President and General Manager • DELTA *U. S.*

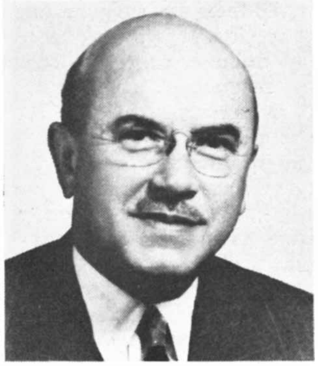
DR. A. PLESMAN, President
KLM *Netherlands*

PRINCE M. PACELLI, President
LAI *Italian*

AIRLIFT!

The giant Douglas DC-6—finest of all modern transports—is now flying or on order for these airlines. No other post-war transport has been chosen by so many carriers. Proved over billions of flight miles, the DC-6 is the most economical to operate of all four-engine transports—even approaching the operating costs of twin-engine aircraft. Douglas believes that the continuing development of outstanding commercial air transports like the DC-6 and the growth of civil aviation are vital to the progress and security of the free nations of the world. Douglas Aircraft Company, Inc.

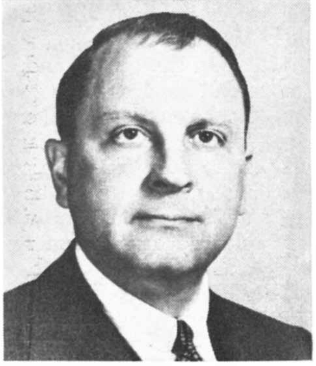
G. T. BAKER, President
NATIONAL *U. S.*



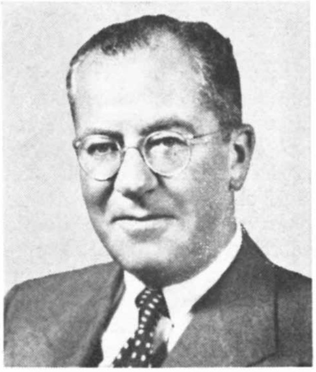
A. SORIANO, President
PAL *Philippines*

PER A. NORLIN, President
SAS *Danish Norwegian Swedish*

G. CLAEYS, Managing Director
SABENA *Belgian*



JUAN T. TRIPPE, President
PAN AMERICAN *U. S.*



ANDREW B. SHEA, President
PANAGRA *U. S.*

THE NEUTRON

The uncharged fundamental particle is used on a vast scale to propagate the nuclear chain reaction and to probe the nature of matter. Of itself, however, it is something of an enigma

by Philip and Emily Morrison

THE periodic table, that ingenious roll call of the elements, lists them in the order of their nuclear electrical charge. They run from the lightest, hydrogen, with a charge equal in size but opposite in kind to the negative charge carried by one electron, to the heavy californium, with a positive charge of 98. The amount of positive electrical charge within the nucleus of an atom determines the number of its electrons, and the number and arrangement of atomic electrons in turn determines the chemical behavior of the elements. Chemistry is fundamentally the study of the atom's shell—the electrons, their arrangement and their laws of motion. It is the electrons alone that determine color, solubility and reactivity, magnetism and electrical conductivity, crystal structure, hardness and strength, indeed all the wonderfully varied properties of matter. The periodic table formed a rational basis for the study of chemistry even before there were elements known to fill all the places in the table. Now every charge number between 1 and 98 is accounted for, and the list is essentially complete; there may only be a few more heavy elements at the end, too unstable to be discovered in nature.

While the 98 elements of the periodic table are chemical elements, there is another that might well be added at the head of the list. There it would be the one element which belongs entirely to the physicist. We call it neutron. In some ways the neutron is the most interesting "element" of all. It has an electrical charge of zero, with no positive charge and hence no atomic electrons. Lacking a cortege of electrons, the neutron has no ordinary chemical or large-scale physical behavior—no color, no chemical compounds, no crystal structure. True, the neutron does interact with light waves, though they are far from the visible region, and it combines with nearly all elements as well as with other neutrons, but these reactions are so different in quality from those of the chemistry of the other elements that the two are not comparable. The neutron is all core and no shell; its behavior is purely nuclear. In an ordinary chemical reaction an atom of one element links with another by gaining or losing electrons from its outer shell, while the nucleus remains unchanged. But when a neutron combines with another element, the electrons are at first largely unaffected, and only the nucleus is changed.

The Neutron and the Nucleus

The electrons moving around the nucleus of an atom form a barrier of negative electrical charge which keeps its distance from the attracting nucleus, and holds the atom separate from its neighbors. Thus, by discouraging the interpenetration of atoms, electrons preserve the identity of different substances. It is true that one cannot store water very long in a bright iron can, because the atoms of iron will, by a series of more or less complicated steps, unite with the atoms of oxygen from the water to form a new atomic arrangement, molecules of the compound rust. Eventually, as enough rust is formed, the can will disintegrate entirely. It is possible, however, to keep water indefinitely in a glass jar and have almost no reaction whatever between the water and the container.

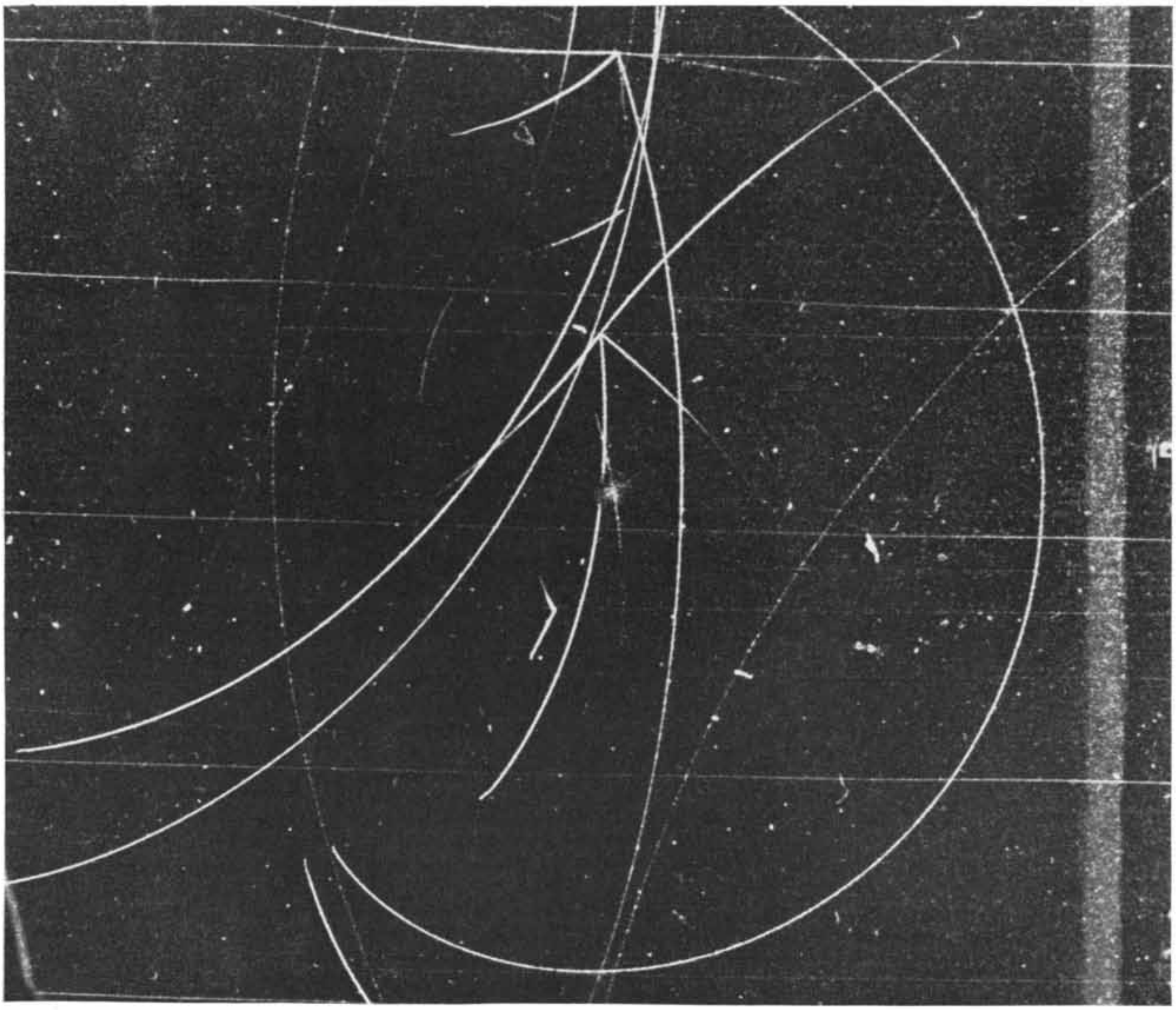
On the other hand, it would be difficult to design any vessel that would hold a gas composed entirely of neutrons for even a few thousandths of a second, since the particles of such a gas would instantly leak into the walls of the container and combine with its atoms. No electric charge can repel the neutron, and it reacts with the nuclei of nearly all elements. When a neutron passes through matter, it cannot be deflected from its course by ordinary electrical forces, but only by the forces that are specifically nuclear. These forces extend a mere 10^{-13} centimeters, a ten thousand billionth of a centimeter, into the space around the nucleus, or some hundred thousandth of the average distance from the nucleus to its outermost electron. A neutron hardly notices the shell of electrons surrounding each atom, but moves freely on its way, often for several centimeters, before it collides directly with a nucleus. Then the neutron may bounce off or stick tight, depending to some degree on the speed with which it is moving. After several collisions the neutron sticks to some nucleus; the neutron gas that had leaked into the walls of our container would gradually disappear as its particles were absorbed.

Just as any other gas, neutrons can at least in thought be compressed to form a liquid droplet of several particles touching each other, a material that would be as dense as anything we know. Since the diameter of the electron orbit of an atom is so much larger than the diameter of the nucleus, and since a neutron liquid has neither atomic electrons nor the volume they loosely occupy, a density of 10^{14}, or a hundred thousand billion, grams per cubic centimeter becomes plausible. A drop of neutrons the size of a drop of water would weigh more than the Washington Monument. The dense nucleus of every atom behaves like just such a tiny droplet of neutrons combined with protons. Ordinary solid matter thus seems to a neutron much like a good vacuum would seem to a moving charged particle. An electron can travel for several centimeters without hitting something only in a good vacuum in which the atoms are widely separated, but a mean free path of this length is commonplace for a neutron, even in solid material. For a charged particle, space is full of great whirling balloons—the atoms. For the neutron, the wall of each atom-balloon is porous and insubstantial, and the only solid obstacle is a tiny central grain of sand.

The Clue of the Isotopes

All the atoms of a given element are chemically identical, *i.e.*, they have the same number of electrons. The weight of their nuclei, however, may differ. By separating from their fellows all atoms of the same weight we obtain a pure isotope. All elements have a number of such isotopes, stable or unstable. The neutron has no long-lived stable isotope, and probably no second, unstable isotope exists either, though a transient association of two neutrons may last for a very few cycles of its internal motion. The neutron itself is unstable—spontaneously radioactive in much the same way as some natural radioactive associates of uranium are. Instead of decaying like radium or uranium by emission of an alpha particle composed of two protons and two neutrons, the neutron decays into three particles: an electron, a proton and a neutrino. This process is called beta decay. It has been predicted theoretically that half of a given number of neutrons will decay in about 10 minutes, *i.e.,* the neutron has a half-life of 10 minutes. Since a neutron lasts only a few thousandths of a second before being absorbed into a nucleus of solid material, the number of neutrons that remain free long enough to decay spontaneously is extremely small and their detection most difficult. Recently some very elegant experiments have confirmed these predictions of theory. While the evidence for the beta decay theory is reasonably clear, the details are far from completely understood. An electron is certainly sent out as the neutron decays, but it is difficult to see how an electron can be inside a neutron in any understandable way, since the volume required by an electron is far larger than the entire volume of the neutron. The electron is created, with the enigmatic neutrino, on the instant of decay. Because most neutrons are absorbed quickly, and even those not absorbed into other nuclei would decay of their own accord in a short time, free neutrons are hard to find. Their natural habitat is nowhere. The rocks, the sea and the air are our sources for all the other elements, but there is no natural storehouse of neutrons. A few are manufactured high in the atmosphere as the result of collisions between cosmic rays and the nuclei of the atoms that compose the air, but only at the rate of about one neutron per square centimeter per minute. A few are made by reactions initiated by radioactivity in rocks. The first neutrons to be discovered were part of a steady stream actually produced in the laboratory.

The early study of isotopes had suggested several reasons why atoms of the same element varied in weight. Among the most popular of these explanations was the notion that the additional weight consisted of extra protons whose charge



CLOUD CHAMBER PHOTOGRAPH shows the effects of neutrons but not the neutrons themselves. The cloud chamber stands beside a cyclotron at the University of California. When 100-million-volt neutrons are directed into the chamber, some of them strike the nuclei of oxygen atoms and cause them to fly apart. The tracks of two such exploding nuclei are at top and center. Their fragments are curved by a magnetic field about the chamber.

was without effect because each was neutralized by an ordinary electron packed within the nucleus. This account was for many reasons unsatisfactory, and in 1920 the great British physicist Lord Rutherford presented his theory of a neutral particle to explain why nuclei were too heavy for their charge, a theory which foreshadowed with remarkable clarity the experiments of 10 years later. Said Rutherford in the Bakerian Lecture before the Royal Society of London:

"[This assumption] involves the idea of the possible existence of an atom of mass 1 which has zero nucleus charge. Such an atomic structure seems by no means impossible. On present views, the neutral hydrogen atom is regarded as a nucleus of unit charge with an electron attached at a distance, and the spectrum of hydrogen is ascribed to the movements of this distant electron. Under some conditions, however, it may be possible for an electron to combine much more closely with the H nucleus, forming a kind of neutral doublet. Such an atom would have very novel properties. Its external field would be practically zero, except very close to the nucleus, and in consequence it should be able to move freely through matter. Its presence would probably be difficult to detect by the spectroscope, and it may be impossible to contain it in a sealed vessel. On the other hand, it should enter readily the structure of atoms, and may . . . unite with the nucleus. . . ."

Beginning in 1930 a series of experiments in Heidelberg by W. Bothe and H. Becker and later in Paris by Frédéric Joliot and his wife Irène Curie produced a kind of uncharged radiation that had penetrating power that was curiously high even for gamma rays, the very short electromagnetic waves. As a source for these new rays the experimenters used a disk of beryllium metal, against which they directed the alpha particles constantly emitted by a member of the radium family. James Chadwick of Cambridge University repeated the experiment with the same kind of source, but directed the suspected new radiation into a Wilson cloud chamber filled with nitrogen. He observed that an occasional nitrogen atom would dart across the chamber as though it were recoiling from an impact much too massive to be caused by a weightless if energetic gamma ray. The events in his cloud chamber looked as though two particles as heavy as nuclei had collided and bounced apart, though the track of only one was visible. From this evidence Chadwick was able to prove that the new rays were not electromagnetic radiation but particles. The particles had a mass very similar to that of the proton but no electrical charge. For this latter reason the particles could not knock electrons from the atoms in the cloud chamber, as they would have to do in order to leave a visible trail. These electrically neutral particles Chadwick called neutrons.

The discovery of the neutron confirmed Rutherford's old prediction and made clear the origin of the extra weight in the nucleus: the protons provide the positive charge of the nucleus, and the neutrons provide the excess weight. Neutrons exist in the nucleus of every element except the single-proton common isotope of hydrogen. In light elements they supply about half of the mass, and in heavy elements they supply much more than half. The nuclei of the two stable isotopes of carbon each contain six protons, which identify them as carbon. But carbon 12 has six neutrons and carbon 13 has seven. The isotopes of uranium each have 92 protons, much less than half the weight of the uranium nucleus. To make up the difference uranium 235 has 143 neutrons, or 51 more neutrons than protons, and uranium 238 has 146 neutrons.

The Production of Neutrons

To study the neutron, as to study any other element, one must first purify it; in this case purification means separating the neutron not from any mere chemical combination but from a tight nuclear bond. Such a physical separation of the condensed nuclear material is far more difficult than even the most obstinate chemical separation, as, for example, that of the compounds of fluorine. From the chemist's point of view the extremely resistant fluorocarbon plastics are tightly bound and stable compounds, but with sufficient effort he can break them down with heat or molten alkaline reagents. The separation of nuclear material, however, involves wholly different techniques. The simplest neutron source is essentially the one used by its discoverers: an inch-long sealed brass capsule in which alpha particles from a radium salt bombard beryllium metal powder. Most of the fast alpha particles come to rest after frittering away their energy against the atomic electrons, never encountering other nuclei. But on rare occasions an alpha particle will collide with a beryllium nucleus and expel a neutron. A good yield is one neutron for every 5,000 alpha particles emitted by the radium. Such a nuclear reaction creates a comparatively small trickle of neutrons. In actual numbers such a trickle may amount to a million per second, but at this rate it would take all of geological time to set free even a single gram of neutrons!

Any source of fast particles or gamma rays with enough energy directed against a target made of a light element will set free neutrons. The prewar physicist typically used fast deuterons, composed of a neutron and a proton, on beryllium in a cyclotron. The intensity of neutrons produced by the deuteron beam of even a modest cyclotron equals that of many kilograms of radium. But if neutrons stream from the largest cyclotron, a veritable Niagara of them bursts from the chain-reacting atomic piles developed during the war. The largest neutron-producing plant of all is that at Hanford, the Atomic Energy Commission's plutonium factory in the state of Washington. Hanford manufactures neutrons as a nuclear reagent, and a few grams of neutron gas are sufficient to make a kilogram of plutonium. About half the weight of every lump of dirt is neutron, since, as we have noted above, the nucleus of almost every atom contains as many neutrons as protons. But a billion-dollar plant can produce in one day an amount of the pure nuclear reagent to be measured only by the ounce. Expensive stuff! Once made, however, this intensely powerful reagent is the philosopher's stone in the large-scale alchemy of the plutonium project.

The Detection of Neutrons

It is a simple but not a trivial matter to detect the presence of neutrons, even in small quantities. Any fast charged particle leaves a wake of charged atoms, or ions, which may easily be recorded on a photographic plate or detected by such electronic devices as the Geiger-Müller counter. Since neutrons have no charge and therefore cannot knock free any atomic electrons, they leave no such track to be recorded. It is possible in principle to detect the accumulation of neutrons by measuring the gain in weight of the material surrounding the neutron source as neutrons are captured. Such a method is impractical, however, because of the extremely small weights involved. Even if one used hydrogen, whose individual atoms' weight would double on the addition of a neutron, there would be so few hydrogen atoms affected that their presence could hardly be noticed among all the others. For special investigations with the most copious neutron sources—nuclear reactors—such measurements can be made with a sensitive mass spectrograph, but even this method is too delicate and complex for any routine detection. For ordinary purposes neutrons may be detected only indirectly through some specifically nuclear effect. One important and typical method employs boron 10. When it captures a not-too-fast neutron—which it can do with a probability nearly unexcelled among nuclei—this boron isotope flies apart into two fragments, one a fast-moving alpha particle and the other a nucleus of lithium 7. Both the alpha particles and the lithium nuclei leave a strong, easily detectable track of ions in their wake. The basis for nuclear reactors and atomic bombs is of course the fission of uranium 235 when it captures a neutron; this phenomenon can also be used to detect neutrons. The fission method of detection, with boron 10 or uranium 235, is most useful for rather slow neutrons. The detection of fast neutrons is often managed differently. A neutron traveling at high speed is not usually captured by the first nucleus it meets; it collides only to recoil. In the collision the neutron slows down, while the nucleus that was hit goes faster than before the encounter; the neutron has shared its kinetic energy with the nucleus it has bumped. By mere impact the fast neutron jolts the target nucleus sharply off its course, usually without disturbing it internally. As it bounds away from the collision, the nucleus leaves many of its electrons behind. Now that the atom has become a charged ion, it leaves a wake of other ions which can be detected. Almost every neutron comes finally to the end of its free life captured by some nucleus; this very efficiency provides still another method of detection. A small foil, say of silver, is exposed to a stream of neutrons. Each silver nucleus that acquires an extra neutron becomes unstable, and within a short time emits a beta particle whose ionizing track may be detected in some standard counter.

Let us trace the career of a free neutron from the moment of its liberation. To do this we may use an ordinary neutron source, a capsule filled with beryllium and radium, placed in a bucket of water. Occasionally, if the circumstances are favorable, a neutron is released from a beryllium nucleus as it is hit by an alpha particle. A steady supply comes out of the capsule in all directions. As each neutron emerges from its nuclear bonds, it is traveling at about a twentieth the velocity of light, with an energy of some millions of volts. The neutron passes through hundreds of millions of atoms in the inch or so it traverses before colliding with a nucleus of hydrogen or oxygen in the water. The fast neutron usually bounces off the nucleus in this first collision, going off in a new direction at a slightly lower speed, while the nucleus is jolted into moving faster than before. With each collision the neutron loses a little more of its original store of kinetic energy, which is taken up by the nucleus that it hits. The nuclei in the water have had the effect of moderating the speed of the neutrons without capturing them, and for this reason water is called a moderator. Many elements with light nuclei are effective moderators. Compounds of hydrogen, oxygen, carbon and beryllium are all satisfactory, but water, graphite and paraffin are most frequently used because they are readily available in pure form. After several hundred nuclear collisions, the neutron has slowed down until its motion is comparable to that of the relatively slow-moving atoms in the water around it. The neutron is still moving at supersonic speed, but this is thousands of times slower than when it was freshly released. Such a neutron which has come to share the ordinary heat motion of the atoms of the moderator is called a thermal or slow neutron. Sometimes a neutron will escape by chance through the wall of the bucket into the air of the room, where, of course, the molecules are far apart compared with those of water. Here the neutron can travel a long distance, often several hundred yards, before colliding with another nucleus. Most of the neutrons in pure water, once they have slowed down, will be finally absorbed by nuclei of hydrogen to form the isotope deuterium, famous as the essential element of heavy water.

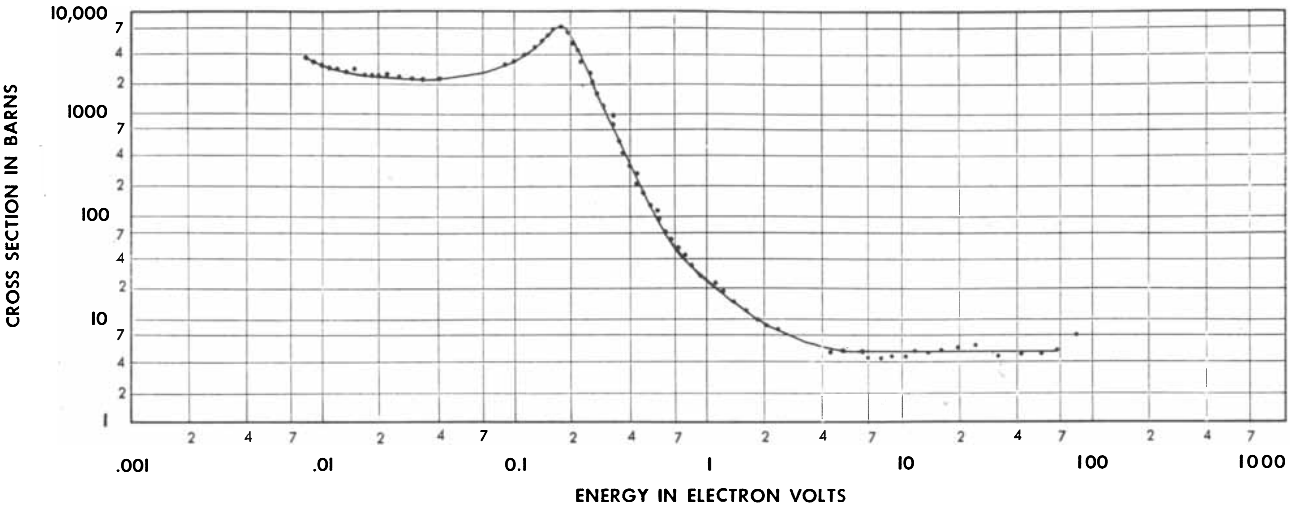
A slow neutron is the most efficient nuclear reagent known. A slow-moving proton or alpha particle is kept far away from a nucleus; the electrostatic repulsion a positively-charged nucleus exerts on a positively-charged proton or alpha particle keeps away all but those with the highest energy. Once a proton or alpha particle has slowed down, it wanders about with no prospect of getting near a nucleus, but instead picks up an electron or two and settles for the quieter life of a stable atom. On the other hand, the slower the neutron, the more likely it is to be captured. No neutron escapes eventual capture by some nucleus, except for the one out of every few million that spontaneously decays. For the physicist who wishes to control the fate of his neutrons the chief problem is one of economy—he must prevent the loss of neutrons, whether through random diffusion out of the apparatus in which he is working, or from capture in the extraneous material within that region. The latter part of the problem is solved by the use of carefully purified moderators so that the neutron will have little opportunity to combine with any unforeseen substance. The former part of the problem resolves into a question of size; to prevent neutrons from diffusing out of his working region the physicist makes the region ever larger. A laboratory where neutron work is done is characterized by large piles of graphite blocks or boxes of paraffin or even tanks of the costly heavy water. Such arrangements are the closest approximation to bottles for the most active of all reagents.

The Neutron as a Wave

Thus far we have spoken of the neutron as a particle, a hard round speck of stuff. But this is only one aspect of the neutron; indeed, it is only one aspect of all the atomic material of modern physics. Not only is the neutron a particle, it is also a wave. This subtle notion of the duality of matter is the fundamental

PARTICLE	CHARGE	MASS
ELECTRON	−	1
POSITRON	+	1
PROTON	+	1836
NEUTRON	0	1836
PI MESON	−	276
PI MESON	+	276
MU MESON	−	210
MU MESON	+	210
NEUTRAL MESON	0	271
V PARTICLE	−	?
V PARTICLE	+	?
V PARTICLE	0	2100 ?
NEUTRINO	0	0 ?

GLOSSARY of the fundamental particles of matter lists their electrical charge (+ or —) or lack of it (0). Also shown is the mass of the particles in terms of that of the electron.

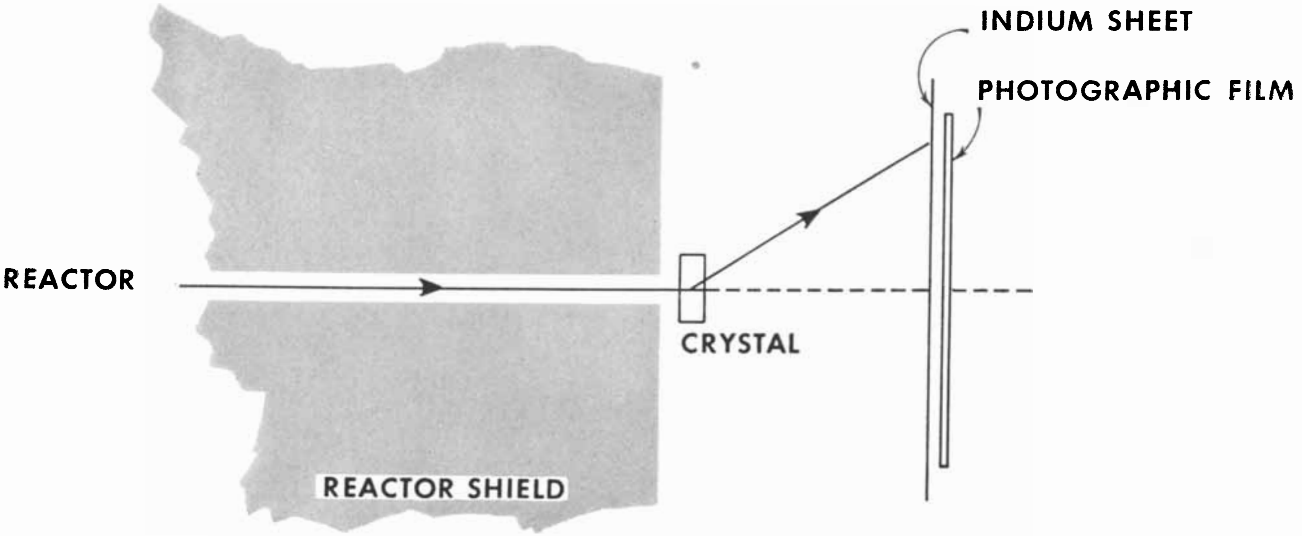


ABSORPTION OF NEUTRONS by the nuclei of the element cadmium is shown by this curve. Each point on the curve indicates the cross section, *i.e.*, the probability of capture, for a neutron of given energy. The "barn" is 10^{-24} square centimeters. The curve shows that cadmium is a very efficient absorber of slow neutrons.

principle of quantum theory, that indispensable language of the modern physicist. Perhaps the most spectacular aspect of the neutron as a wave is the phenomenon of nuclear resonance. Resonance is the familiar but always marvelous concomitant of any periodic disturbance. In its essentials nuclear resonance has much in common with a child on a swing. By gentle but carefully timed pushes, adjusted to the particular swing, the child can send the swing far above the bar from which it is suspended. What happens when a neutron wave encounters a nucleus? Of course the nucleus is a little sphere with three dimensions, and neutron waves encounter it from all sides. But for simplicity let us use a one-dimensional analogy; then the nucleus has simply a front and a back edge which lie in the path of the neutron wave. The analysis required to extend this picture more realistically to three dimensions we can leave to mathematics. Now when a wave strikes any obstacle, part of it goes on, but some of its energy is scattered back. In our one-dimensional case both the front and back edges of the nucleus send a small portion of the wave back in the direction whence it came. If it happens that the portion diffracted by the back edge returns to the front edge in such a way as to be precisely in step with the incoming wave, we have a condition of resonance. The incoming wave is reinforced by the diffracted wave. Stronger now, the incoming wave will again diffract at the back edge and contribute a portion of itself, still in step after a complete round trip across the nucleus, to the next incoming crest. If these waves are exactly in step they will reinforce indefinitely; the amplitude of the wave inside the nucleus will, after many internal traversals, become very large. If we use the quantum language to translate wave into particles we find we have been saying that captured neutrons are very likely to be found within the nucleus. The reinforcement requires that the time between successive incoming wave crests precisely match the time for the interior wave to complete the round trip across the nuclear obstacle. The incoming wavelength, which is fixed by the energy of the neutrons, will determine the entire course of events. For exactly the right wavelength, or neutron energy, the match will be perfect: the nucleus will voraciously absorb neutrons; for an energy just a trifle different, the nucleus will be almost transparent to neutrons. The resonance can be broad or narrow, just as a tuned radio circuit can have a sharp or broad response. The study of resonant energies and the breadth of their peaks comprises the study of all internal motions of the nucleus. The study is vigorously pursued by physicists over the whole range of neutron energies and over all available target nuclei. What is especially interesting for physicists who study nuclei with neutrons is the great effectiveness of slow neutrons. The fact that neutrons have no electric charge and thus experience no electrostatic repulsion means that they can interact strongly with nuclei even when very slow. A beam of thermal neutrons moving at about the speed of sound, which corresponds to a kinetic energy of only a fortieth of an electron volt, produces nuclear reaction in many materials much more easily than a beam of protons of millions of volts energy, traveling thousands of times faster. A doubling of the neutron energy represents a large and thus easily measurable percentage change, but corresponds to a small fraction of a volt energy increase, a variation which would be undetectably small against the million-volt energy of the charged-particle beam. An energy change of a few thousandths of a volt is enough to carry the neutrons across an entire nuclear resonance peak. This enormous and unexpected magnification of the first volt or so on the energy scale—the energy range occupied by slow neutrons—is perhaps the single greatest aid to the unraveling, still very much unfinished, of the structure of all but the lightest nuclei. It is a little out of our scope, but worth the digression, to point out that on the energy scale the position of just one of the millions of resonance levels which could be observed for a uranium nucleus is decisive for the success or failure of the slow-neutron chain reaction. Special devices that produce beams of neutrons of a single and carefully controlled energy are used for the study of nuclear resonance. These devices, which have been made in wide variety, depend on crystal effects or on careful mechanical or electrical timing of neutron flight to produce their single-energy beams. At somewhat higher energies the experimenter manages to use nuclear reactions for the generation of neutrons which are of such a kind that the neutron energy varies as he varies the energy of the charged-particle beam that produces the reaction. The whole neutron energy range from zero up to a few million volts has been studied with some care. The first important volt is now expanded into a thousand analyzed stretches; clearly for sheer bulk of information such a detailed study cannot be spread over a million volts.

Neutron Diffraction

The wavelength of thermal neutrons is several angstrom units, comparable to the distance between atomic nuclei in a crystal (an angstrom is a hundred millionth of a centimeter). The neutron wave can thus be diffracted by crystals.



DIFFRACTION OF NEUTRONS has been used to study crystals by C. G. Shull and E. O. Wollan of Oak Ridge National Laboratory. In their experiments neutrons escape from a reactor through a quarter-inch hole in its shielding. When the neutrons are diffracted by a crystal, they make spots on a photographic plate.

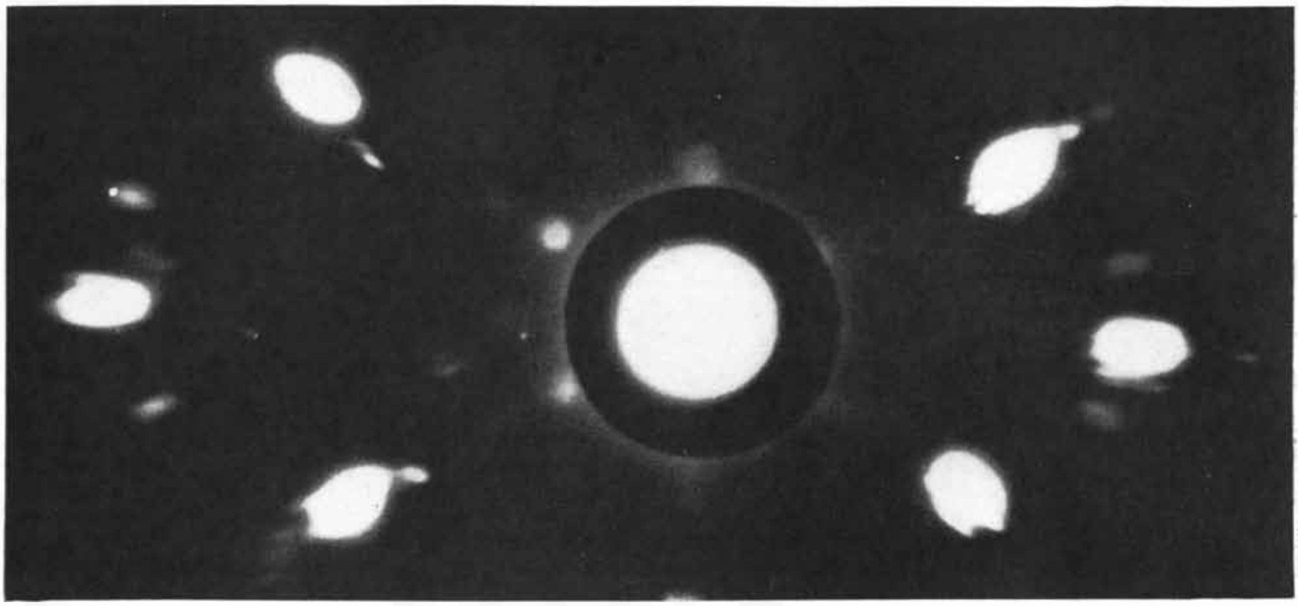
To clarify the notion of diffraction, hold under a lamp a microgroove phonograph record slanting away from your eye, and you will see a series of rainbow colors. This is the diffraction pattern made by light waves striking the grooves. The space between grooves is 50 times the wavelength of visible light, but this is fine enough to show visible, though rather crowded, patterns. For precision optical work, where clearly defined and widely separated diffraction patterns are essential, the physicist uses glass carefully ruled with some 10,000 parallel grooves to the inch. Each groove scatters the light that hits it, and the regularly spaced array of grooves works to reinforce the light scattered in a few special directions to form regular diffraction patterns. The sharp definition of these patterns depends on the precise spacing of the grooves. For the diffraction of X-rays, whose wavelength is thousands of times shorter than that of visible light, no man-made rulings can be fine enough. The regularly spaced atoms of crystals, however, make an excellent submicroscopic diffraction grating. The physicist has used X-ray diffraction techniques for decades to study crystal structure. The geometric arrangement of atoms within a crystal is made vivid by the famous Laue spots, the dots on a photographic plate made by X-rays diffracting from rows of electrons within the crystal. Now just as X-rays are scattered by the electrons of atoms in a crystal, neutrons are scattered by the nuclei of such atoms. The physicist today has added a neutron source and detector to the standard X-ray diffraction apparatus so that diffraction techniques may now be applied to the study of nuclear properties. The diffraction of slow neutrons is also useful to those who study crystal structure by diffraction. In ordinary X-ray diffraction pictures the very light atoms like hydrogen can hardly be detected, especially when they are found combined with heavy atoms in some crystal; the few electrons of the light atoms are masked by the many electrons of the heavy atoms. In neutron diffraction electron charges have no effect, and only the nuclei show. Light nuclei may be seen as well as heavy ones, often even better because their diffracting properties depend not on weight but on specific nuclear differences. Among the most recent studies made possible with this new technique has been one of the structure of the crystal ice; this confirmed previous indirect assumptions about the location of the hydrogen nuclei in a network of frozen water molecules.

Even more familiar than diffraction are refraction and reflection. All three are properties which depend on the fact that waves can be scattered. In diffraction the responsible scattering centers are individual, regularly-spaced obstacles, but in reflection or refraction the scattering is the statistical summation of the effects of all the atoms of the material involved. Visible light can be reflected from a glass or metal mirror at almost any angle; X-rays and neutrons can be reflected appreciably only at low angles. In some recent investigations neutrons have been reflected from the mirror surface of a liquid mixture of hydrocarbons, *i.e.*, compounds of hydrogen and carbon. This experiment has made possible a precise and complete measurement of the various interactions of the neutron with carbon and with the proton of hydrogen. Because of the comparatively simple "optical" nature of the experiment, such interactions can be studied by measuring the angles at which complete neutron reflection takes place. Once such interactions could be observed only by making measurements, never very accurate, of the passage of neutron beams—regarded as a stream of particles—through waxy filters. The neutron-hydrocarbon reflection studies, though essentially the studies only of neutron wave effects, throw a direct light on the behavior of the neutron as a particle.

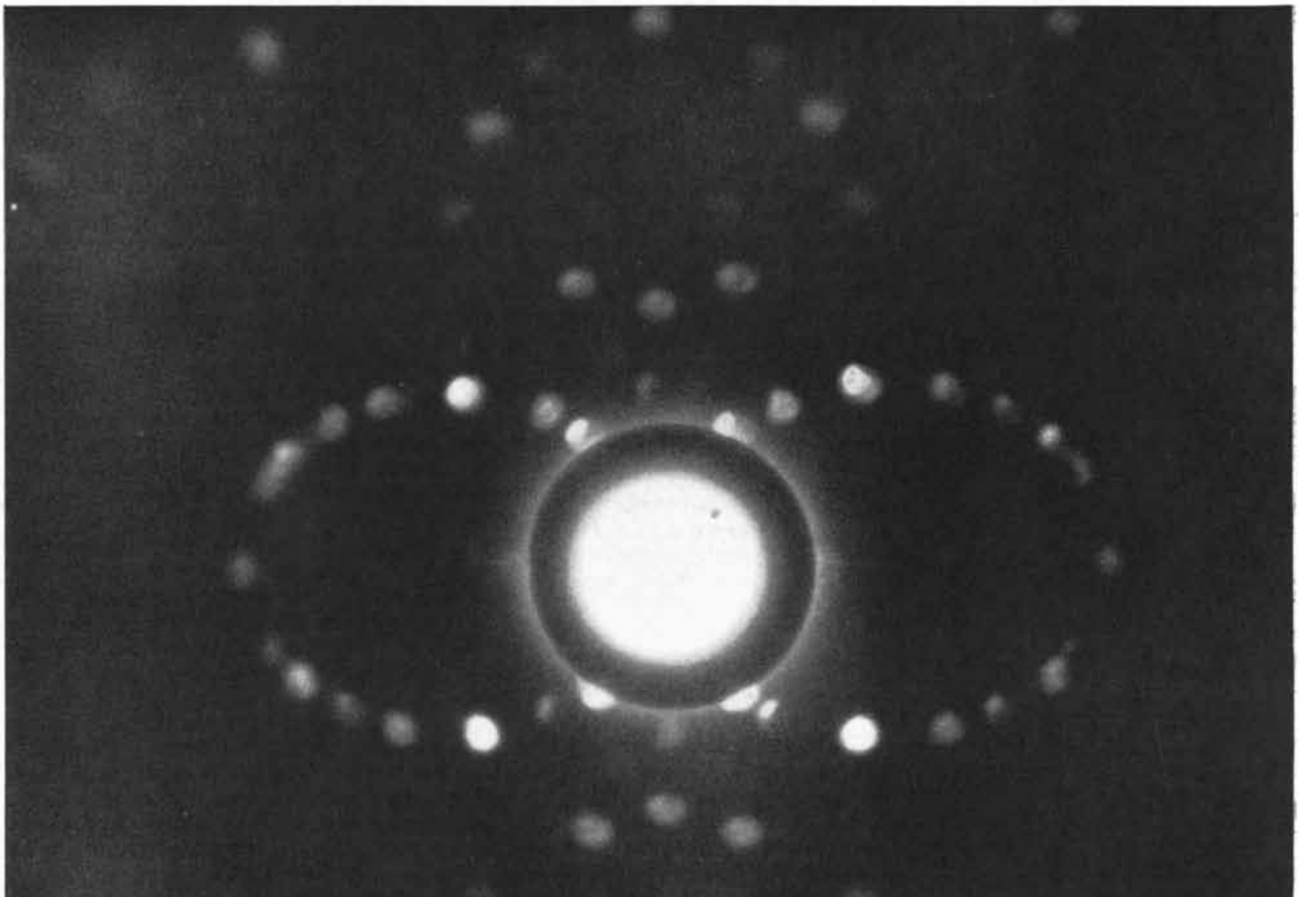
New Questions

Up to now we have discussed facts about the neutron, the hard core of facts which have been tested experimentally and are clearly understood. But in the 20 years since the neutron was discovered, a great many new questions have been raised. Some of them have been answered definitively, but many others remain unsolved. Let us consider these latter questions, along with most physicists. If we were to plot on a graph the growth of the physicist's understanding of the neutron, we would have a reasonably smooth ascending curve for the first 10 or 15 years, but during the past few years we would have a profusion of scattered points with no one clearly defined direction. Perhaps after another decade the dots will have formed a clear pattern, and the curve will continue to a peak of real understanding. At present, however, the status of the neutron as a fundamental particle is far from clear. What follows is a summary of current ideas: shaky speculation combined with firm experiment.

Is the neutron really neutral? Up to the time the neutron was discovered, all other particles known to have a mass also had an electric charge. The question of neutrality has been troubling physicists since the day neutrons were discovered. Charged particles are deflected by electric or magnetic fields; Chadwick himself tried in vain to deflect the neutron with an electric field. His successors have likewise failed to observe any de-



BERYLLIUM CRYSTAL is photographed by the technique depicted on the preceding page. The principal utility of neutron diffraction for crystal studies is to show the position of light atoms masked by heavier ones.



QUARTZ CRYSTAL makes a neutron diffraction pattern different from that of beryllium. Like X-ray diffraction patterns, neutron diffraction patterns can be mathematically read to locate the atoms in a crystal.

flection of even the slowest neutrons with the strongest electric fields. Charged particles knock electrons from atoms, leaving ions; no ionization has ever been noticed along the track of a neutron except when charged particles have recoiled as the result of a direct hit on a nucleus. The beta-decay experiments which showed that the neutron decomposes into a proton and electron—two particles of equal and opposite charge—confirmed all the previous assertions as to the over-all electrical neutrality of the neutron. It was found long ago, however, that the neutron has magnetic properties, that it lines up like a compass needle of a tiny but definite strength or "magnetic moment" in an experimental magnetic field. The deuteron, which, to repeat, consists of a neutron and a proton, was found to have a magnetic moment only about one-third that of the proton by itself. The proton was known to have almost three of the natural nuclear units of magnetic moment. The difference between the moment of the deuteron and that of the proton was accounted for by an assumed magnetic moment for the neutron of about minus two units. This assumption was confirmed by direct measurement in an experiment done just before the war. Just as iron filings can be guided by a magnet, so it was found that slow neutrons could be deflected from their course by passing them through magnetized iron. For the first time the effect of a magnetic field on a neutron was clearly observed. The minus sign for the neutron's magnetic moment indicates that the direction of the neutron's magnetic poles is mechanically opposite that of the proton's. One may visualize the neutron and the proton as tiny gyroscopes, each with a bar magnet as its axis. If a neutron and a proton are spinning in the same direction, their magnets will point in opposite directions.

It is very difficult to believe that the neutron can be magnetic and yet be associated with no electrical charge whatever. Recent experiments seem to indicate, in fact, that the neutron consists of a positively-charged core surrounded by a thin shell with an equal quantity of negative charge. Again to repeat, the neutron responds primarily to nuclear forces which reach only some 10^{-13} centimeters into space, while the distance from an atomic nucleus to one of its electrons may be 100,000 times as far. The neutron thus rarely hits an electron; at any reasonable distance the neutron appears entirely neutral, its interior positive charge canceling out its exterior negative one. If a neutron comes very close to an electron, so that the electron lies partly within the negatively-charged shell, the neutron should no longer appear entirely neutral. In the experiments done to test this hypothesis, slow neutrons were scattered from the atoms of xenon. Xenon is the heaviest and hence the most electron-rich of all the inert gases. These gases form no chemical compounds whatever. The theory of atomic structure can explain this property by the circumstance that the electrons in such gases are arranged so that their magnetic effects cancel completely. The magnetic moments of the electrons are paired off, each moment canceled by one aligned in the opposite direction, so that there is no possible net magnetic interaction between a xenon atom and any external magnet such as a neutron. Now the nuclei of atoms scatter very slow neutrons uniformly in all directions, essentially because nuclear interactions are localized at the very center of the atom. If the atoms of xenon scattered neutrons unevenly in various directions, it must be because there is some interaction between the electrons of xenon and the neutrons. But this could not be magnetic: the magnetic forces canceled. Yet each electron acted as a weak scattering center, its effect being about a thirty thousandth as strong as that of the nucleus. The net result was not entirely unambiguous, but together with related experiments it indicates that the neutron does indeed interact, though very slightly, with the electron's charge. There is no doubt that the neutron has a charge-bearing structure, though it is neutral overall.

Neutrons in Nature

In the earth and the air around us, indeed in our very bodies, there is always a perceptible background of neutrons. The radium-beryllium source used to produce neutrons in the laboratory has its counterpart in nature, both deep in the earth and high in the air. Rocks, though almost entirely composed of light elements, generally contain small quantities of heavy radioactive elements. Occasionally alpha particles released by these atoms of the radioactive uranium family strike against and react with the nuclei of the abundant silicon or magnesium atoms within the rock, just as they strike the nuclei of beryllium in a laboratory source. The result of these collisions within the rocks is a small, steady glow of neutrons, a few of which inevitably escape into the air. An even richer source of natural neutrons operates high in the atmosphere, mostly above six miles. There the harsh rain of primary cosmic rays beats down on the atoms of the atmospheric gases. When one of these high-energy cosmic particles encounters the nucleus of an atom, the nucleus explodes into fragments; the pronged image left by such an explosion in a cloud chamber or photographic plate is called a "star." Each of the many rays of the star corresponds to the track of a charged particle released in the explosion. For every particle leaving a visible track, however, usually one neutron goes off leaving no track at all; some neutrons travel through the air for miles before being slowed and captured. The production of neutrons in rocks and in the upper air is a slow process compared to the wholesale production of the laboratory. But as far as neutron energy is concerned, the neutron trickle from rocks and the neutron bursts of cosmic rays are roughly two extremes. Neutrons set free in the laboratory run the gamut of energies in between, sometimes indeed a bit lower than those made in rocks, but not yet and perhaps never as high as those made in some cosmic ray explosions.

Since the discovery of the neutron, and largely with its help, a tremendous lore about the transmutations of nuclei has developed. In place of the chemist's familiar periodic chart of the elements, the wall of a nuclear laboratory anywhere displays a nuclear isotope chart which plots all the known stable and unstable nuclei. This chart is a compact summary of facts the detailed description and analysis of which would fill a good many volumes. Each nucleus has its own square, whose position on the chart is determined by the number of protons and neutrons in the nucleus. Within each square is packed a vast amount of abbreviated information. From this chart one can tell which nuclei are stable and how abundantly these stable isotopes occur in nature; the half-lives of unstable elements and the particles they emit; and what nuclear reactions occur when the particles are captured. *The Physical Review,* like every other journal of physics, is constantly filled with papers reporting the discovery of new isotopes and new properties of known isotopes, so that a nuclear chart is barely printed before it needs revision. The crowded nuclear chart is, of course, merely a symbol for the whole study of nuclear reactions, vast enough to constitute an independent branch of physics. The experimenter has measured and described in detail as much as he can of the events which occur in a long series of possible nuclear reactions. If, for example, he bombards boron 10 with neutrons of a given energy to produce lithium 7 and alpha particles, he counts the number of alpha particles and lithium nuclei and then calculates the probability for the reaction to occur. The boron hit by a neutron generally produces a gamma ray in addition to lithium 7 and an alpha particle of less energy than before. He counts the number of gamma rays also and determines the degree of competition which this alternative to the first reaction represents. He uses his instruments to observe the boron target from many different angles and notes the rate of alpha particle production at each angle. He varies the energy of his incoming neutrons and studies the effect of such variation on the yield of all the reaction products. The study of the neutron-boron 10 reaction outlined sketchily here has been repeated in greater or less detail for literally hundreds of different reactions. All the facts and figures assembled in these many experiments have tended to confirm the fundamental picture upon which the physicist builds: the nucleus is a tightly-bound collection of protons and neutrons whose structure he intends to unravel.

Cosmic Rays

The climax of this intensive study of nuclear reactions is the study of the really high-energy events such as the biggest cosmic ray explosions and the reactions recently produced by the high-energy particle accelerators of the post-war years. By exposing photographic plates to cosmic rays the physicist can display in minute detail the complicated pattern of an event which occurs to a single atom, but with an enormously concentrated energy in a thousand millionth of a second. He is able to do this because each charged particle released in the explosion radically disturbs each tiny crystal of the photographic emulsion through which it passes, in just the same way that light disturbs such crystals in ordinary photography. Because the sensitive emulsion of the photographic plate is a layer no thicker than a sheet of heavy paper, the path of a particle through it is very short, unless by happy accident it is closely parallel to the plane of the emulsion. Any detailed examination of the individual crystal grains in the emulsion requires a microscope. Seen through a microscope the track of a fast proton, say, appears to be an irregular row of tiny dark dots, each dot representing what was once a translucent grain of silver bromide, so affected by the rude passage of a charged particle that it turned to a black metallic speck of silver when the developer solution reached it. Because they do not leave the tracks of charged particles, neutrons cannot be seen directly, but their presence in cosmic rays is made abundantly clear by their other effects. After a painstaking examination of such a cosmic ray photograph, the physicist is able to describe an explosion in detail. He knows which particle set off the explosion, since he can learn its mass, charge and energy by measuring such quantities as the grain spacing and the deviations of its tortuous path through the emulsion. He measures in the same way the tracks of all the various particles produced by the explosion. From these studies of nuclear explosions have emerged a whole series of facts which play an important part in our knowledge of nuclear reactions.

The most exciting find resulting from the observation of cosmic ray explosions in photographic emulsions was the "pi meson," a new particle which interacts with neutrons and protons. Pi mesons have a mass about one-sixth that of a proton. Three kinds occur: one with a positive charge, one with a negative charge and one with no charge at all. Such mesons are transient; when free they last only a hundred millionth of a second and usually travel only a few feet in air. Although they are intrinsically so different, one may draw an analogy between the role of mesons and that of light "particles," or quanta. When electrons are ripped from an atom, the energy and momentum of the electromagnetic field of force which holds the charged particles of the atom together are partly released in the form of light quanta which travel out into space indefinitely, far from the disturbed atoms. We say that the light is radiated. Now if we consider the nucleus to be a collection of neutrons and protons held together by nuclear forces, we may by analogy expect that when a nucleus is disturbed and ripped apart, the energy released appears partly in the form of mesons, which play the same role for nuclear forces as light quanta do for the electromagnetic binding forces of the atom. In each case the very action of rearranging an existing structure, either atom or nucleus, creates something new which radiates afar. In one case we have light quanta, which have no charge and no mass, and in the other case free mesons, which have both charge and mass. This notion of a complete analogy between light quanta and mesons is an extension of the idea of treating the nucleus as a kind of condensed atom. If we look at the nucleus this way, the forces that hold it together involve a kind of incessant exchange of mesons between the nuclear particles. The idea was first clearly expressed by the Japanese physicist Hideki Yukawa about 15 years ago, and it has remained a major guide for such investigations ever since. For some time the study of mesons was confined to their analysis in cosmic rays, but new particle accelerators have been able for three years to make mesons artificially. Meson research is now going forward vigorously in many laboratories. Several different types of mesons have been discovered in a very few years, but of these the pi meson just now appears to be most closely related to nuclear forces. It is the origin of these forces that remains unclear.

The Crisis of Physics

The crisis in physics centers about difficulties in the concept of fundamental particles. Physicists believe that protons and neutrons are fairly permanent constituents of nuclear matter, and in this sense they are fundamental. In no nuclear reaction at present-day energies does the total number of neutrons and protons change. The fundamental problem is still *why* these fundamental particles act as they do. Physicists have a reasonably clear and detailed picture, as we have seen, of *how* the neutron and proton act, and the experimenter can to a large extent control their interactions. So far so good. But the theory lags; real understanding is scant. Consider the electron. While the physicist cannot predict the charge or the mass of the electron, he can, given these numbers, fully account to six decimals for the magnetic moment of the electron. He can calculate in detail at any energy the interaction of electrons with each other and with light. This gives some confidence that the electron, whose properties are described so completely and so economically by the equations of the English physicist P. A. M. Dirac and the recent brilliant extensions of electromagnetic theory, is in a practical sense a simple and fundamental particle. Given a very few of its properties, the rest follow from the theories in rich detail. But as we have seen, this is not so for the nuclear particles, the proton and the neutron. The essential feature which seems to distinguish the cases is the strong interaction between the proton and neutron on the one hand and the meson on the other. We cannot even approximately regard the neutron or the proton as a well-defined and stable fundamental particle. On the contrary, these particles must be described as regions of interaction. A neutron must be pictured as a "bare" nuclear particle around which mesons steadily form and disappear. These are genuinely transient mesons; it is impossible to observe them as real particles, for the very process of observation disturbs the whole system enough to release them as free mesons, no longer bound. A neutron that became briefly a proton and a negative pi meson, or several mesons with net electrical charge of zero, and then recombined, would account graphically for some of the puzzling properties of this "fundamental" particle. The tentative picture is not unattractive, but it is quantitatively incorrect and generally intractable.

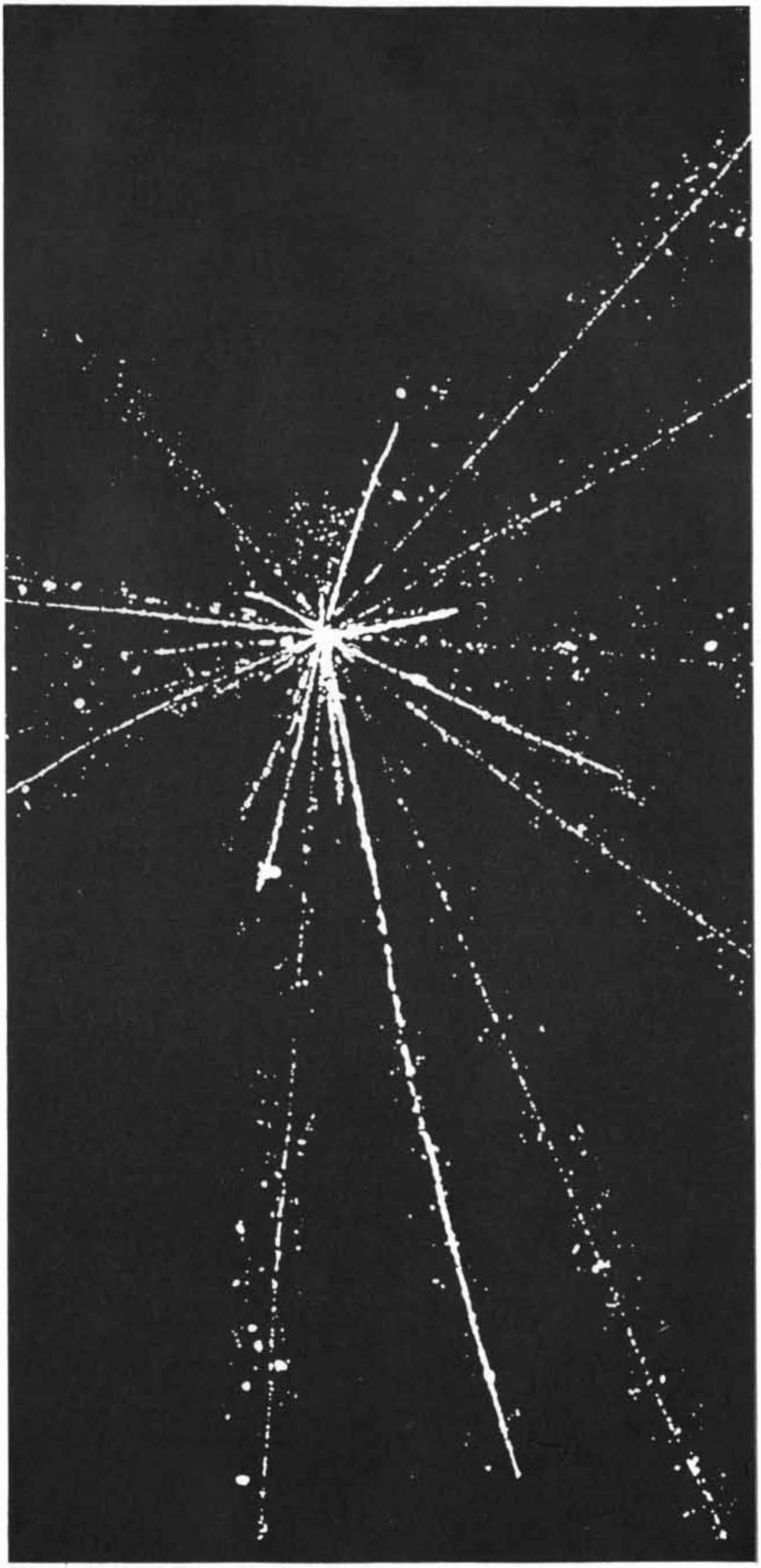
This rough working hypothesis is reinforced, however, by the observation that a neutron and proton may change places during a collision. A fast neutron goes by a proton and a fast proton comes out traveling in almost the same direction, while a neutron recoils rather slowly. This particular phenomenon occurs too often to be accounted for by a direct hit, which is after all a relatively rare occurrence; it must be happening even when the neutron merely passes fairly near the proton. Such an event could be accounted for by a transfer of a charged meson between the neutron and the proton. There may be many such exchanges. There is also some evidence, convincing but indirect, that electrical currents other than those accounted for by the motion of the proton flow in the nucleus.

The existence of nuclear forces of this type implies the easy transfer of charge between the proton and the neutron. The interaction of the many protons and neutrons in the nucleus under conditions which allow the flow of mesonic currents means that the identity of a nuclear particle is not fixed. The total charge remains immutable, but just which nuclear particle is a proton and which a neutron is a question that must be answered differently some 10^{20} times per second. The nucleus is no static realm of wandering planets, however pretty a picture this makes for the textbooks.

The Limits of Understanding

Our ignorance of the neutron curiously emphasizes the great strides that physicists have made in their understanding of the nucleus as a whole. They have classified a great number of nuclear reactions. They understand fairly well those reactions which occur in the upper atmosphere through the agency of cosmic rays and those induced by the beams of accelerating machines. They have learned how to manage and predict nuclear reactions, from those of the simple radium-beryllium sources to those of the fission processes of the uranium and plutonium bombs. They now have a considerable insight into the complex structure of nuclei. But physicists have only a confused and fleeting knowledge of the real nature of the parts which comprise that structure. The neutron and the proton can no longer be considered the fundamental and immutable building blocks of matter. The current list of "fundamental" particles now includes, in addition to the proton and neutron, the electron, the positron, the mu meson, the pi meson, the recently discovered V particles, the neutrino and the photon, or light quantum. Not all of these can be fundamental in any real sense of the word. The whole concept of matter must be extended somehow to include the different aspects of these particles in some unifying theory. Probably the real fault lies with the idea that one can separate out a fundamental particle. Some view of the joint and mutual interaction of the many "fields" of the particles whose tracks are so patiently and beautifully exhibited is perhaps the direction of the answer. But as in so much of physics the power of understanding is great but sharply and paradoxically circumscribed. The physicist controls the chain reaction, he catalogues the nuclear levels by thousands, he lists the artificially produced isotopes and their properties in grand array. But the inwardness of the neutron lies for a while beyond his understanding.

Philip Morrison is a physicist at Cornell University. Emily Morrison is his wife.



COSMIC RAY "STAR" was recorded in photographic emulsion by physicists of the National Research Council of Canada. The star represents the explosion of a silver or bromine nucleus struck by a high-energy cosmic ray.

RADIATION FROM A REACTOR

The photograph on the cover is the first to reveal the interior of an operating atomic pile. Of special interest to the physicist is the blue glow that surrounds the chain-reacting fuel elements

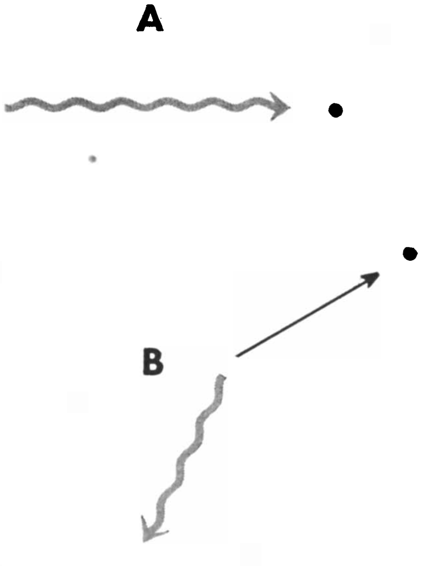
by W. H. Jordan

ON the cover of this issue of SCIENTIFIC AMERICAN is an historic picture. It is the first photograph to show the interior of a nuclear chain reactor in actual operation. Suffusing the reactor, which is located at Oak Ridge National Laboratory in Oak Ridge, Tenn., is a curious blue glow; indeed, the reactor is photographed by its own light. This radiation has a special fascination for the physicist. What kind of radiation is it, and what is its cause?

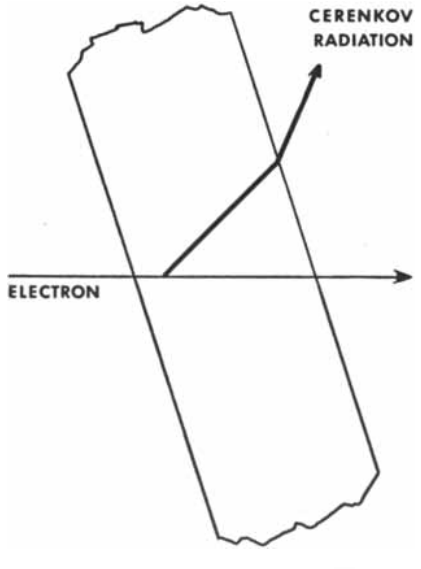
In 1934 the Russian physicist P. A. Cerenkov observed that when a flask of water was irradiated with gamma rays from radium, the water emitted a weak bluish-white glow. This is not surprising when we consider that many substances fluoresce when irradiated with gamma rays, X-rays or even ultraviolet rays. However, upon further investigation Cerenkov showed that the light emitted by the water was quite different from that given off by fluorescent materials. First, the spectrum of the light was continuous from red to ultraviolet, showing none of the band structure usually associated with fluorescent radiation. More remarkable, the light was emitted chiefly in the direction of the gamma ray beam instead of radiating in all directions. In addition the light was strongly polarized. The effect was not confined to water; other transparent substances such as glass and mica showed essentially the same behavior. Here was a new and unexplained phenomenon. No reasonable explanation was advanced until three years later, when two other Russian physicists named Frank and Tamm published a paper on the theory of Cerenkov radiation. They showed that such radiation is quite in accord with the prediction of electromagnetic theory.

It is well known that when gamma rays pass through matter they are absorbed by the electrons of the atoms comprising the matter. The mechanism for this absorption was first given by the U. S. physicist Arthur Holly Compton, for which he was awarded the Nobel Prize. According to Compton one must picture the gamma ray beam as consisting of a stream of energetic particles, or photons, which make billiard-ball-like collisions with the electrons. A head-on collision between photon and electron will transfer a large fraction of the photon energy to the electron. For example, a photon with a million electron volts of energy can transfer 800,000 electron volts of energy to the electron. Now an electron with 800,000 electron volts of kinetic energy travels with a velocity of 2.77×10^{10}, or 27,700,000,000, centimeters per second. This is very nearly the velocity of light in vacuum (3×10^{10} centimeters per second) and considerably greater than the velocity of light in, for example, water (2.25×10^{10} centimeters per second) or glass (2×10^{10} centimeters per second). Frank and Tamm showed that charged particles moving through a medium with a velocity greater than that of light in the medium must give off radiation of the type observed by Cerenkov.

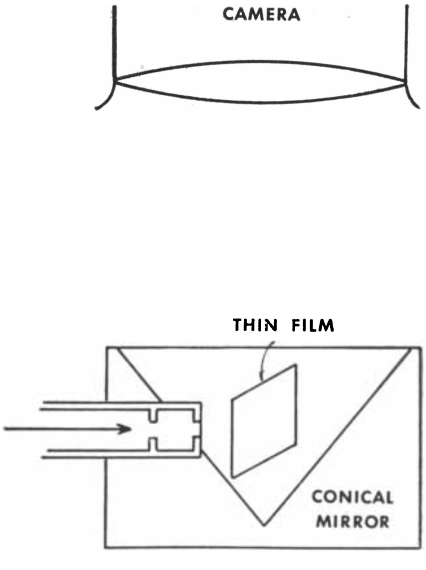
The situation is somewhat analogous to that of a boat moving through water with a speed greater than the velocity of waves on the surface of the water. Everyone is familiar with the V-shaped bow wave that is generated in this instance; the greater the speed of the boat, the smaller the angle of the V. In the case of a charged particle moving in a dielectric, *i.e.*, a non-conducting, me-



COMPTON EFFECT would account for fast electrons in a nuclear reactor. Gamma ray (*wavy line*) imparts some of its energy to electron (*dot*).



CERENKOV RADIATION goes off at an angle when an electron passes through a medium at a speed greater than speed of light in that medium.



PHOTOGRAPHY of Cerenkov radiation was achieved by Collins and Reiling by firing electrons from the source at left through thin films.

dium, a cone of radiation is produced, the angle of the cone being a measure of the speed of the particle.

Thus it appears that the radiation observed by Cerenkov came not from the gamma rays but rather from the high-speed electrons produced by the gamma rays. The predictions of the theory can therefore best be tested by using a beam of electrons that have approximately the same energy. In 1938 George B. Collins and Victor G. Reiling, then of Notre Dame University, sent a beam of electrons from a two-million-volt accelerator through thin films of various substances and photographed the resulting Cerenkov radiation. The photographs at the right are taken from their paper. The photograph at the upper left shows the radiation produced in willemite, a common fluorescent material. As shown by the uniformly illuminated circle, copious quantities of radiation are produced in all directions. (The breaks in the circles are due to mechanical obstructions in the path of the light.) The remaining pictures were taken with thin samples of clear dielectrics in the electron beam. Instead of a full circle of light, we now see two preferred directions corresponding to the opposite sides of the cone of radiation. Since the velocity of light in each of the various dielectrics was different, the angle between the spots of light should be different. In mica the angle was 53 degrees 30 minutes; in glass it was 45 degrees 15 minutes; in cellophane it was 50 degrees. These angles were in excellent agreement with the predictions of the theory.

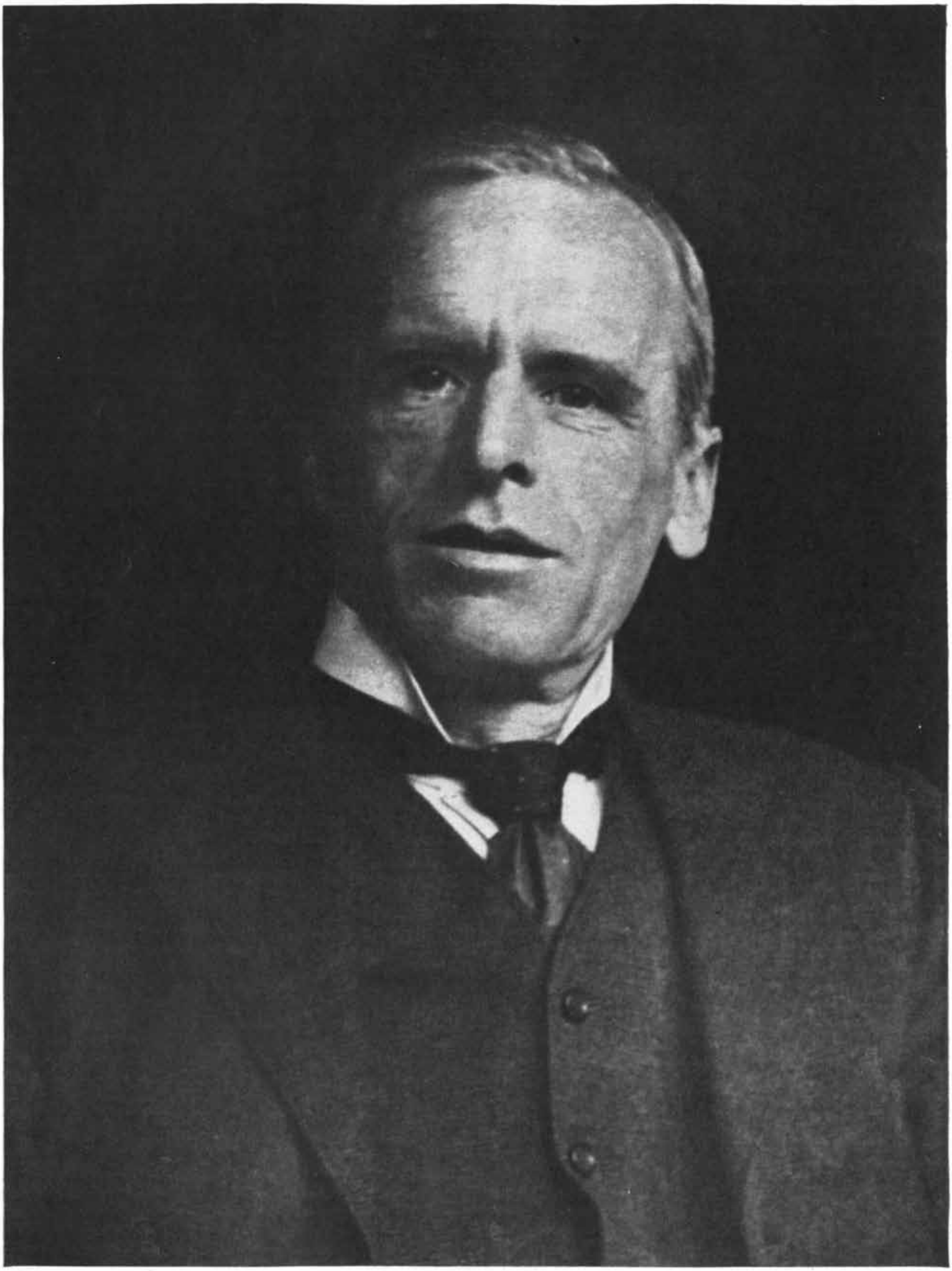
While the early experiments of Cerenkov showed that light was given off by water when radiated by gamma rays, the intensity of the light was very weak. The successful operation of nuclear reactors has given us gamma ray sources many orders of magnitude greater than were previously available. The uranium slugs in the graphite reactor at Oak Ridge, for example, become tremendously radioactive. When some of them are discharged into a deep, water-filled canal behind the reactor, a diffuse bluish glow surrounds each slug. The glow is also seen around the highly radioactive cobalt 60 sources that are stored in the same canal.

The most brilliant display is observed when an entire reactor is operated in a tank of water; the photograph on the cover was made under such conditions. But the question arises, is this glow really Cerenkov radiation? Certainly the experiments described above would lead one to expect such radiation under the circumstances. Nevertheless the possibility exists that some other process accounts for most of the observed light. Conclusive experiments are difficult to perform; however, our calculations indicate that the observed intensity of light is about that expected from the Cerenkov effect. We have looked at the light through a hand spectroscope and observed a continuous spectrum extending from the red through the violet. Furthermore the radiation from regions near the sides of the reactor is partly polarized; complete polarization would not be expected even if all the light were due to the Cerenkov effect. Consequently we are of the opinion that a sizable fraction, and perhaps all, of the mysterious blue glow is Cerenkov radiation.

◆

W. H. Jordan is a physicist at Oak Ridge National Laboratory, operated by the Union Carbide and Carbon Company for the Atomic Energy Commission.

CERENKOV RADIATION IMAGES were photographed in the apparatus shown on the opposite page. The image at upper left was produced by shooting electrons through willemite. The other images, reading from left to right, were produced by mica, glass, cellophane and thick and thin films of water.



ERNEST HENRY STARLING was born in London in 1866 and died in 1927. When he graduated from Guy's Hospital in 1890, he became lecturer in physiology. Later he was professor of physiology at University College.

Ernest Starling

The great English physiologist discovered hormones and the Law of the Heart. Although his name is remembered by his scientific successors, it has been forgotten by history to a curious degree

by Ralph Colp, Jr.

THE word hormone comes from a Greek verb meaning to excite. It is an apt name, for nothing in physiology or medicine today is more exciting than the unfolding story of the remarkable role that hormones play in controlling life. The beginning of that story also is exciting, but not well known. Usually a great discovery in science is inseparably associated with a great name; thus the word relativity is practically synonymous with Einstein, gravity with Newton, heredity with Mendel and the circulation of the blood with Harvey. The hormone certainly ranks among the most important discoveries of all time, but it is doubtful that many people could name the man who discovered the hormones' vital significance as chemical messengers in the body. His name was Ernest Henry Starling. It is a name well known to physiologists but almost forgotten to history, in spite of the fact that Starling was one of the giants of science in the early part of this century.

Starling's discoveries were not confined to the hormones; he made equally important contributions in the very different fields of explaining the flow of body fluids and the beating of the heart. Indeed, one of his followers described him as "the last physiologist to know and master all branches of physiology."

Starling is a particularly appealing figure because he epitomized the best qualities of science in his time—the end of the 19th century and the opening of the 20th. In an age marked by great optimism and eagerness in science, Starling was notable for what his friends described as a "boyish enthusiasm" that persisted throughout his life. At 57, delivering the annual oration in honor of William Harvey before the Royal College of Physicians in London in 1923, he said:

"When I compare our present knowledge of the workings of the body, and our powers of interfering with and controlling these workings for the benefit of humanity, with the ignorance and despairing impotence of my student days, I feel that I have had the good fortune to see the sun rise on a darkened world, and that the life of my contemporaries has coincided not with a renaissance but with a new birth of man's powers over his environment and his destinies unparalleled in the whole history of mankind."

Starling himself had had a great deal to do with ushering in this new birth. Spurred by the conviction that science would eventually cure not only physical disease but social evils in general, he had spent his zestful life attacking, and solving with remarkable success, some of the most difficult problems that challenged science, not only in his laboratory but in Great Britain's national life.

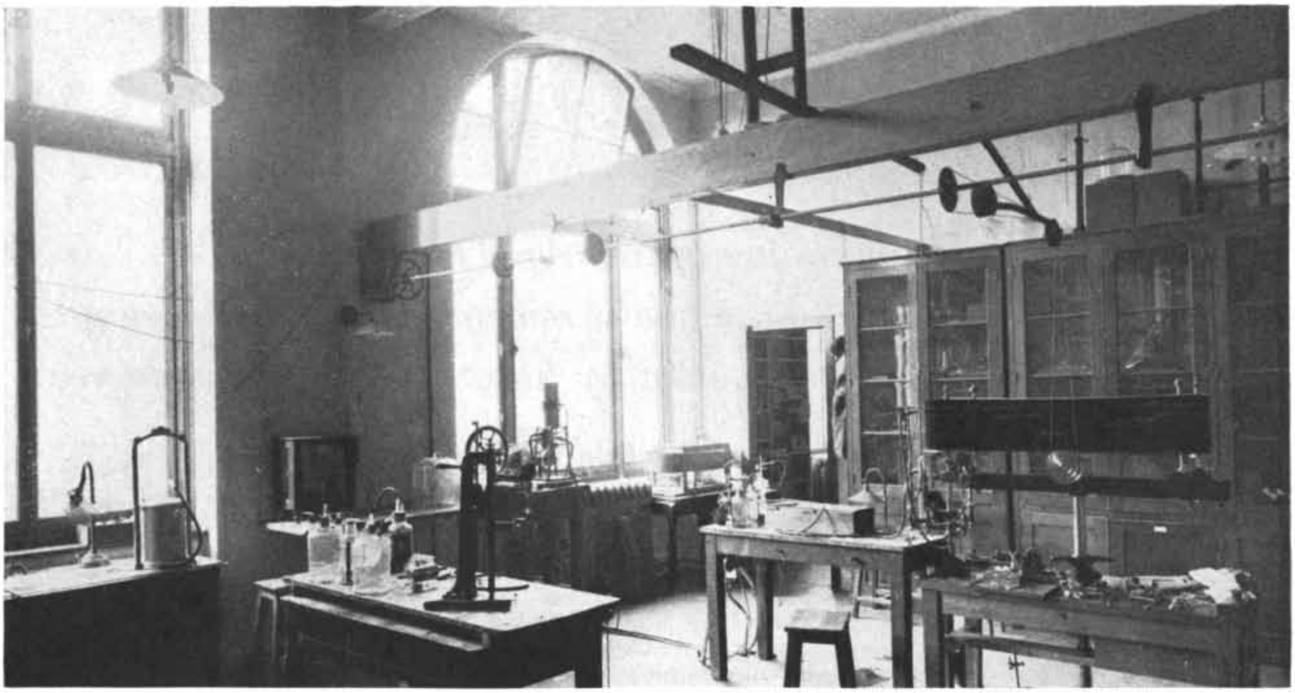
BORN in London, the son of a clerk to the crown, Starling at the age of 16 entered the famous Guy's Hospital in his native city to study medicine. His original ambition was to practice as a doctor in Harley Street. But long before he got his M.D., he had decided that research in physiology attracted him far more. It was in several ways an intrepid, pioneering decision. Few British men of science before him had tried to make a living solely in research; they had generally supported themselves by some other occupation and regarded science as an amateur hobby rather than a profession. Moreover, physiology in England was still in the early frontier stage. Work in this field had been mainly descriptive; the famous doctors of Guy's Hospital in the past—Bright, Parkinson, Addison, Hodgkin—had obtained immortality by attaching their names to a description of a disease. The study of the processes and functions of the body, by means of new techniques made possible by chemistry and physics, was just beginning.

Starling set forth on this new path. With several other English scientists of his own generation—Charles S. Sherrington, John S. Haldane, Joseph Barcroft, Frederick G. Hopkins—he was to become one of the founders of the great English school of physiology that for a time led the world in this field.

When he graduated from medical school at 24, Starling took a position as a lecturer in physiology at Guy's Hospital, on a salary so meager that he needed a supplementary grant from the British Medical Association to support himself. But the laboratory facilities at Guy's were poor, and Starling soon moved to a better-equipped laboratory in London's University College.

There he met another young physiologist who was to become his lifetime partner in research. The man was William Bayliss, who had got bored with his study of anatomy in medical school and, like Starling, had resolved to devote his life to physiology, obtaining a Ph.D. in this field at Oxford University. The two men were physical and temperamental opposites. Starling was lean and clean-shaven, Bayliss stubby and bearded; Starling was high-strung and impetuous, Bayliss placid; Starling was an organizer and man of action, Bayliss more reflective and erudite (co-workers called him "The Encyclopedia"); Starling was little interested in mechanical details, Bayliss an excellent mechanic who enjoyed inventing technical apparatus. They complemented each other perfectly, and for more than 30 years, until Bayliss' death in 1924, they worked together in a scientific partnership which one might almost call a romance. (The tie was strengthened by the fact that not long after they met Bayliss married Starling's sister.)

Starling carried out his first great investigation, however, largely on his own. He set out to find the answer to one of the major puzzles in physiology: How did the circulatory system produce lymph—the watery, transparent fluid that bathes the tissues? Lymph comes to the tissues from the bloodstream through the walls of the small blood vessels, the capillaries. The question was: What happens at the wall to form the lymph, in such a way that the membrane separates



STARLING'S LABORATORY at University College was equipped with apparatus designed by him and his colleague Bayliss. At the far right is a kymograph to record physiological phenomena in experimental animals.

two different fluids, lymph on one side and blood on the other?

The situation might be explained by purely physical processes occurring through the membrane: namely, diffusion, filtration, osmosis or a combination of them. The German physiologist Carl Ludwig had shown in 1850 that the flow of lymph apparently depended on the blood pressure in the capillaries, and this had been accepted as support for the diffusion-filtration theory. But in 1891 another German, Rudolf Heidenhain, found that when the general blood pressure was reduced by obstruction of some of the major blood vessels, the flow of lymph did not decrease, as expected, but sometimes actually increased. Furthermore, he showed that it was possible to increase the formation of lymph by a chemical method; that is, by injecting peptone or sugar into the bloodstream. There was no increase in blood pressure, yet more lymph, and in a more highly concentrated form, passed to the tissue cells from the capillaries. This seemed to support the idea that the capillary walls themselves might form lymph by some chemical means.

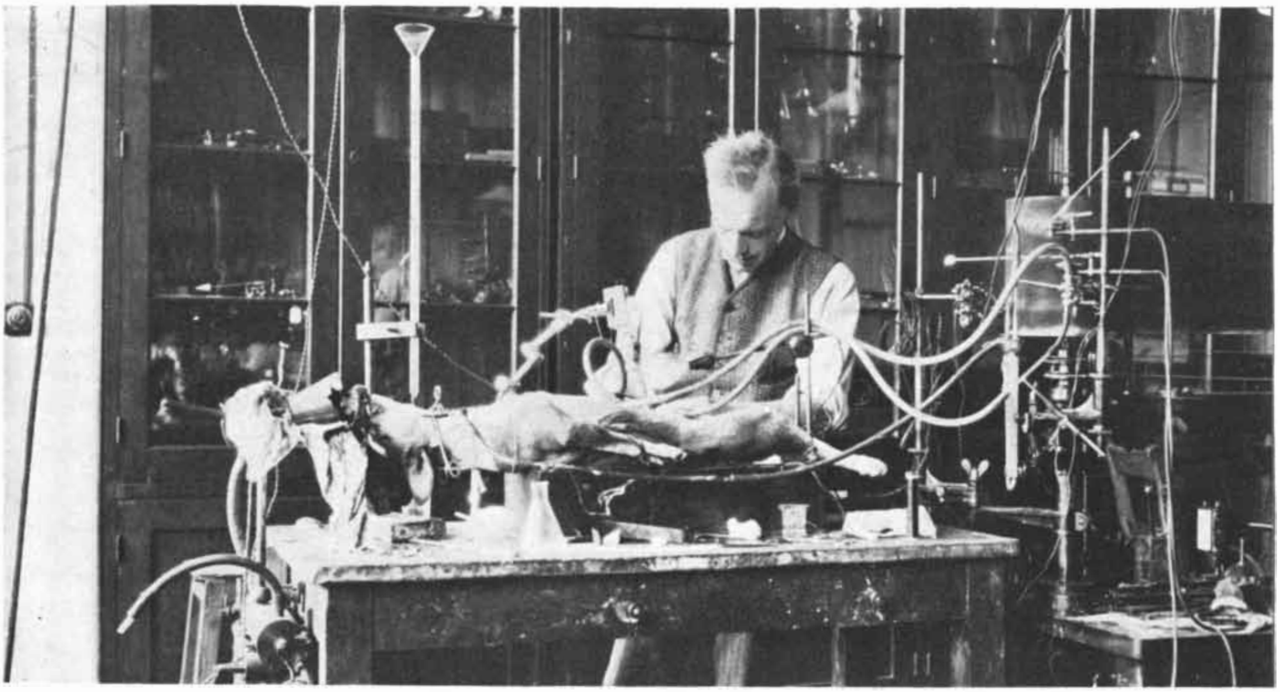
STARLING began his investigation of the problem at the University of Breslau, where he had gone to work under Heidenhain. In his first published paper he concurred with Heidenhain's finding that the capillary walls appeared to create lymph chemically. But Starling was not satisfied; he thought it should be possible to find an explanation in physical law. He returned to England and repeated some of Heidenhain's experiments himself. He found, as Heidenhain had, that when he obstructed the aorta and inferior vena cava, reducing the body blood pressure, the flow of lymph increased. For over six months he tried vainly to locate the source of the extra output of lymph, until, in his own words, he was "almost in despair." And then he discovered it in the capillaries of the liver. He found that although the obstruction of the two large blood vessels produced a fall in the general body blood pressure, there was a local rise of blood pressure in the liver capillaries. In accord with the laws of fluid forces, this causes the liver capillaries to pour out more lymph and so increase the general body lymph.

Starling now reinvestigated Heidenhain's experiments with injections and found that they too could be explained in physical terms. The injection of peptone, he showed, produced a greater and more concentrated flow of lymph because it injured the cells of the capillary wall and thereby increased the membrane's permeability. The injection of sugar, on the other hand, produced its effects by osmotic pressure. Its presence in the bloodstream pulled fluid from the tissues into the blood vessels. This increased the filtration pressure in the capillaries, which in turn forced an increased flow of a more concentrated lymph out through the capillary walls.

After three years of work along this line, Starling was able to declare that lymph production depends upon the pressure of fluids within the capillary and the permeability of the capillary wall. He had shown how fluids pass out of the capillaries. But Starling was also interested in the other half of the story: How do fluids pass from the tissues *into* the capillaries?

For 50 years it had been a point of hot debate as to whether blood capillaries could take up fluid at all. Starling proved that they could, and went on to show how they did it. It was well known that the protein molecules in the blood never pass out through the capillary walls, because they are too large to filter through the pores in the membrane, and that the small salt molecules in solution in the blood circulate freely back and forth through the walls. Starling constructed a model of the situation to observe the flow of fluids. Using a membrane which, like the capillary walls, was permeable to salt but impermeable to protein, he placed a salt solution on one side of the membrane and blood serum, containing proteins and salt, on the other. He found, as he had anticipated, that the osmotic pressure of the blood proteins pulled the lower-density salt solution through the membrane and into the blood serum. With this experimental device Starling was able to make precise measurements of the osmotic pressure of the blood proteins.

Having shown how the capillaries take up fluid, Starling was now able to draw a general picture of the movement of fluids back and forth across the capillary walls. In the arterial part of the body's circulatory system the blood pressure is high enough to drive fluids through the capillary walls into the tissues, where they deliver oxygen and



STARLING'S WORK was divided into several phases, one of which was the study of digestion. This photograph shows him at work on a dog. Much of Starling's success as an experimenter was due to his skill as a surgeon.

nutrients to the cells. In the capillaries of the venous side, where the blood pressure is lower, the osmotic pressure of the proteins takes charge and the fluid flow is mainly into the vessels. Here the capillaries draw in fluids containing carbon dioxide and other metabolic waste products to be carried away and excreted.

Hundreds of quarts of fluid pass in and out of the human blood stream through the capillary walls each day. The fact that the blood volume remains constant is evidence of the accurate balance struck between the hydrostatic pressure exerted by the pumping of the heart and the osmotic pressure of the blood proteins. Were it not for the latter, a man would lose the whole of his serum into his tissue spaces within 10 seconds. The back-and-forth movement of fluid between the capillaries and tissues facilitates the exchange of substances so that the fluid bathing the body tissues is maintained constant in all its properties.

Starling's picture still stands as the framework of our understanding of the vital exchange of fluids between the bloodstream and the body tissues. When he started this work, he was an unknown youth of 26; when he finished, at 31, he had revolutionized some basic concepts and stood in the forefront of physiology.

THE NEXT problem that attracted Starling's energies was the new frontier which had recently been opened by his great Russian contemporary Ivan Pavlov—the physiology of the intestine. How did digestion work; what was the mechanism that produced the digestive juices; how did they act on food; what controlled the movements of the alimentary canal? Pavlov had developed ingenious surgical methods for exposing to view the digestive processes and products in living animals, and he had concluded from his analyses that digestion was largely under the control of the nervous system.

Starling, teaming up now with Bayliss, began with a study of the intestine's movements. They worked out their own apparatus for doing this—a kymographic machine in which the experimental animal's intestine was connected to a stylus that recorded its movements as a wriggling curve on the smoke-blackened surface of a sheet of paper wrapped around a rotating drum. From these records, which were able to capture the essential movements of the gut, Starling and Bayliss deduced that the muscular tube of the intestine operates under a dual system of controls. The local nerves in the wall of the intestine signal the presence of food. The intestinal muscles above the food then contract and those below it relax—a peristaltic movement which results in propelling the food down the canal.

Starling and Bayliss corroborated Pavlov's finding that the movements of the intestine were controlled by the autonomic nervous system. They then turned to the question of the secretion of juices by the pancreas, an intestinal gland. Were these secretions also controlled by nerves? Pavlov's work suggested that they were, and Bayliss and Starling set out to try to prove this hypothesis. But they made a completely unexpected discovery, in a historic experiment of which, fortunately, we have an eyewitness account. The witness was C. J. Martin (later director of the Lister Institute), and he described it in these words:

"I happened to be present at their discovery (January 16, 1902). In an anesthetized dog a loop of jejunum was tied at both ends and the nerves supplying it dissected out so that it was connected with the rest of the body only by its blood vessels. On the introduction of some weak hydrochloric acid into the duodenum, secretion from the pancreas occurred and continued for some minutes. After this had subsided, a few cubic centimeters of acid were introduced into the loop of intestine. To our surprise a similar marked secretion was produced. I remember Starling saying, 'Then it must be a chemical reflex.' Rapidly cutting off a further piece of jejunum, he rubbed its mucous membrane with sand in some weak acid, filtered it and injected it into the jugular vein of the animal. After a few minutes the pancreas responded by a much greater secretion than had occurred before."

"It was," Martin added, "a great afternoon!" For what the experiment had shown, and Starling had instantly realized, was that the body possessed a chemical means of communication—a blood-borne chemical signal which, like a nervous impulse, could trigger an organ into action. Starling and Bayliss soon identified this chemical and gave it the name secretin. They found that it came from the wall of the intestine. When acid from the stomach enters the intestine, it causes the wall to liberate secretin. The substance then travels in the

bloodstream and stimulates the pancreas to pour out the pancreatic juices that aid in the digestion of food.

Secretin was not the first internal secretion to be discovered; physicians were already acquainted with adrenalin, thyroid extract and some of the other powerful substances produced by the glands. But Starling was the first to grasp the master role that these substances played in the communications and regulation of the body, and it was he who gave them the general name of hormones—a word suggested by one of his fellow workers. From a more or less accidental discovery Starling drew a great generalization which he later expressed as follows:

"It was not until the discovery of secretin by Bayliss and myself in 1902 that we recognized that these so-called internal secretions were merely isolated examples of a great system of correlation of the activities, chemical and otherwise, of different organs, not by the central nervous system but by the intermediation of the blood, by the discharge into the bloodstream of drug-like substances in minute proportions which evoked an appropriate reaction in distant parts of the body."

AT THE age of 36 Starling had already achieved two sweeping discoveries, either of which would have been sufficient to assure its author an enduring place in the history of science. He was to make still a third great contribution, and in this he followed in the path of William Harvey, whom he called his "great predecessor." Starling had always been fascinated by the remarkable capacity of the heart to adapt its output to the great range of demands made on it. How does this marvelous pump work so that sometimes it puts out as much as 32 quarts of blood per minute and at other times only about four quarts per minute, and each time as the body demands it? In 1911 Starling settled down to a determined study of this matter with the aid of an ingenious apparatus known as the heart-lung preparation. It consists, in brief, of the heart and lungs cut from an animal's body with the lesser pulmonary circulatory system in it kept intact. By perfusion with blood from which the clotting factors have been removed, such a heart may be kept beating for a whole day after it has been removed from the animal. Pavlov and others had previously used the heart-lung preparation but Starling added a device by which he was able to reproduce artificially the resistance to the heart's pumping which in the body is provided by the capillaries at the periphery of the arterial network.

He showed that the output of the heart was generally independent of peripheral resistance and increases in the rate of its beat, but it varied directly with increases in the inflow of blood from the veins. He found that the increased inflow of venous blood stretched the heart muscle and that the lengthened heart muscle was then able to produce a more forceful contraction, thereby expelling more blood. In short, the heart output was regulated by the mechanical stretching and contraction of heart muscle—the more stretching, the more output. Starling published this discovery, which he called the "Law of the Heart," in 1914.

STARLING'S energies were not confined to his laboratory. As a friend wrote of him, he "was destined by his outstanding and thrilling personality to dominate and lead," and he exerted such leadership in several extracurricular fields. During World War I, when the German blockade cut off food imports to England, he helped formulate a program for feeding the English nation. One of his chief recommendations became a basic British policy: namely, that England's land be used as far as possible to grow grains and vegetables rather than animals.

Starling also put his prestige and organizing genius to work to build up Britain's medical establishment. As a young man he conducted a drive that succeeded in equipping Guy's Hospital with new laboratories. Later he led in building a vast medical center around University College; indeed, at one stage he took off four years from his laboratory research to devote full time to this undertaking. The crux of his plan was to associate a hospital with the teaching and research facilities of a university, in order to coordinate clinical and laboratory attacks upon disease. The University College center was one of the first medical centers organized on the grand scale that is now so familiar in England and the U. S., and Starling had the satisfaction of seeing his ambitious project completed in 1923 with a final grant of funds from the Rockefeller Foundation.

IN MAY, 1927, in the midst of his laboratory work on the heart, which he had resumed after World War I, Starling died suddenly at 61. At the end of his life he was more than ever convinced that science had brought about "a new birth of man's powers over his environment and his destinies," and that the future was unbounded. He wrote: "In science . . . no advance is final. Every question solved produces new riddles to answer, since every higher step gives us a wider outlook and the power of seeing problems which from a lower level were not apparent. It is this, indeed, that gives to science its absorbing interest and makes it a fit occupation for a lifetime."

Ralph Colp, Jr., is a resident surgeon at Mount Sinai Hospital in New York.

HALLOWEEN

The eve of November 1 is both a solemn religious occasion and a time of games and pranks. Many of its customs descend from a Druidical holiday that involved burning men in cages

by Ralph Linton

IN THE U. S. Halloween has become what the sociologists term a "degenerate" holiday. As the eve of Allhallows, or Hallowmas or All Saints' Day, it is one of the most solemn festivals of the church. While devout Catholics go to church on this evening, for the public in general Halloween is a roistering holiday, a night when children in fantastic masquerade ring doorbells and demand "trick or treat," when merrymakers gather to experiment in mock seriousness with superstitious spells and eerie games. The witch with her black cat is the presiding deity of the occasion,

ON HALLOWEEN IN IRELAND at the turn of the century the country folk paraded in honor of Muck Olla, a figure whose origin has been forgotten. Led by a man wearing a mask in the shape of a horse's head, the proand its rituals stem from practices which the church spent much energy and let much blood to exterminate. In our celebration of Halloween we have bypassed the Christian world and gone back to the mystic days of the Druids.

All the holidays of the Christian calendar have their roots in the pagan past, but most are drawn from widespread customs of the ancient world. Halloween seems to come fairly directly from the Druidical cult. This is clearly demonstrated by the fact that Halloween is celebrated by games and spells and rollicking masquerades only in Scotland and Ireland, the last strongholds of the Druids, and in the U. S., where these quaint folk customs were imported chiefly by the Irish. In Latin America and most of Europe, Halloween is a solemn religious occasion when the faithful attend extra masses and say prayers for their dead.

The Celtic order of Druids originated in Gaul about the second century B.C. By that time the Gauls had had considerable contact with the Greeks; the order may have been modeled on some of the Greek mystery religions. However, the Druid rites also included savage and primitive elements. They were eerie enough to satisfy the Halloween thrill seeker, but they lacked the spirit of fun.

THE FIRST of November on the Druidical calendar was the Celtic New Year's Day, the end of the growing season, the beginning of winter and "the light that loses, the night that wins." It was also the festival of Samhain, Lord of the Dead. As the end of the growing season, when the harvest was safely stored against the winter, it was also a time when the Sun God was thanked for ripening the grain and strengthened for his coming battle with the cold.

On this night Samhain was believed to assemble the souls of all those who had died during the previous year. For their sins these souls had been confined in the bodies of lower animals. On the New Year, their sins having been expiated by the ordeal, Samhain released them and sent them on their way to the Druid heaven.

Horses, the animals sacred to the Sun God, were sacrificed as part of the ritual. Human sacrifices were offered up also; the victims were usually criminals who had been rounded up for the occasion. These unfortunates were confined in cages of wicker and thatch made in the form of giants or huge animals. The cages were set afire by the priests and the hapless occupants roasted alive. This unhappy practice was outlawed by Roman command after the conquest of Britain. In A.D. 61 Suetonius ordered the Druidical groves of human sacrifice and augury destroyed.

The old rites nevertheless survived in attenuated form. In medieval Europe there was a weird survival of the Druid burnings: on Halloween black cats were put into wicker cages and burned alive.

cession stopped at farms and begged for butter, eggs and other produce.

ON HALLOWEEN IN THE U. S. today children beg for candy and other edibles. This custom possibly originated with the procession of Muck Olla.

THE PANTHEON of Rome, an old pagan temple, was dedicated to the Virgin Mary and the martyrs in 609. The feast of St. Mary and the Martyrs was first held on May 13 and later celebrated as All Saints' Day on November 1.

The cat sacrifices were made in the conviction that the cats were the familiars of witches, or were even the witches themselves, since it was commonly believed that witches often transformed themselves into cats.

In Britain horses were sacrificed at the feast of Samhain as late as A.D. 400. Even after the Christians had seized the pagan temples and consecrated them to the worship of God, oxen were sacrificed on Hallowmas, sometimes being led down the church aisles and slaughtered before the altar. Bede's *Ecclesiastical History of the English Nation* quotes a sixth-century letter from Pope Gregory the Great to Abbot Mellitus, instructing him to tell Augustine, the first Archbishop of Canterbury, that "the temples of the idols in that nation ought not to be destroyed but that the idols should. The sacrifice of oxen in pagan worship should be allowed to continue, but that this should be done in honor of the saints and sacred relics."

Another odd survival of these ancient rituals is reported for Ireland at the turn of the century by Wood Martin in *Traces of the Elder Faiths in Ireland.* On Halloween (still called Oidhche Shamna, Vigil of Samhain, in some parts of Ireland) the rustics in the district between Ballycotton and Trabolgan paraded through the district begging in the name of "Muck Olla." The identity of Muck Olla has evaporated in the mists of the past, but the name is probably a perversion of that of some Druid god. The procession was led by a man in a white robe wearing a horsehead mask. He was called Lair Bhan (White Mare). This undoubtedly harks back to the sacrificing of white horses to the Sun God on the feast of Samhain. Following the Lair Bhan were a guard of young men tootling on cow horn bugles, and the rest of the celebrants trooped after them.

At each farmhouse the procession halted and called out the master while the Lair Bhan recited a long string of verses, the purport of which was that the farmer's prosperity was due to the goodness of Muck Olla and that if he wished to continue to prosper, he had best make a generous contribution to the representatives of that spirit. The farmers, taking no chances with Muck Olla's displeasure, made liberal offerings, mostly in kind. The procession staggered home at the end of the evening laden with butter, eggs, corn, potatoes, wool and other farm produce. The present custom among children of dressing in outlandish costumes on Halloween and begging from house to house may well have its roots in the Muck Olla procession of Ireland.

Hallowmas was not incorporated into the Christian calendar until fairly late. Since the first of November was already associated in the popular mind with the thronging of the spirits of the dead, it was reasonable that this date should have been chosen as a time to honor the hallowed dead. The church has always found it expedient to incorporate harmless pagan ideas into Christian ritual.

ALLHALLOWS is a feast of the church designed to commemorate all deceased saints known or unknown. The earliest known general ceremony in honor of martyrs was one held in Antioch on the Sunday after Pentecost. In 609 Pope Boniface IV consecrated the old Roman temple called the Pantheon and dedicated it to the Blessed Virgin and all the martyrs. The first feast of St. Mary and the Martyrs was held on May 13, 610. In the eighth century Pope Gregory III dedicated an oratory in St. Peter's to all the saints and fixed the anniversary of All Saints' Day as November 1. In 834 Pope Gregory IV established this festival in the calendar to be observed by all churches.

All Saints' Day was introduced into the church ritual because there were not enough days in the year to make it possible to dedicate a special day for each saint of the Catholic Church. It was also recognized that many martyrs and other faithful whose lives had been worthy of sainthood had never achieved canonization. So this day commemorates saints unknown as well as those honored by the church.

All Souls' Day follows All Saints' Day on November 2. This festival is designed to commemorate those who, although they have not suffered martyrdom or achieved sainthood, have died in the faith. It is dedicated particularly to those who have passed away during the preceding year and whose souls can be helped on their journey through purgatory by the prayers of the faithful.

The feast of general intercession for the souls of the dead was originated by Odilo, abbot of Cluny, who died in 1048. Odilo ordered this observance in his Cluniac monasteries, of which there were more than 300. The custom spread to other congregations as well. By the end of the 13th century the celebration of All Souls' Day was practically universal in the church.

IN both pagan and Christian days the period from nightfall on October 31 until sunset on November 2 seems to have held a mystic and eerie significance. At this time the unseen world of the spirits appeared to be closer to the mundane sphere than at any other date in the calendar. It had been dedicated to the souls of the dead since the Druidical priests called upon Samhain to release the souls and send them on their way. Most religious orders have celebrated a Day of the Dead. Egypt held this festival at the time of the winter solstice on the anniversary of the death of Osiris. Food was spread for the homecoming spirits. At dusk rows of oil lamps were fastened outside the housefronts so that the wandering ghosts would not lose their way in the dark.

In Greece the festival of the dead was held in February and was known as the Feast of Pots. This was because pots of food were laid out for the spirits who thronged up into the land of the living on that day. The Greeks feared to offend their ghostly visitors, but they regarded the invasion without enthusiasm. They smeared their doorposts with pitch in an attempt to keep the spirits from entering and locked all the temples lest the ghosts find their way inside the holy places and linger there beyond their allotted time. The Romans had a feast of the dead called the Feralia, when they visited cemeteries, decorated the graves and left food for the ghosts.

On All Souls' Day in medieval times, criers dressed entirely in black walked the streets ringing a mournful bell and calling on all people to remember the poor souls in purgatory. In London the church bells used to toll all day on November 2 until Queen Elizabeth ordered this clangorous procedure stopped. It was popish nonsense, she said, and the din was offensive to royal ears.

EDITOR'S NOTE

A more extended account of the subject of this article may be found in *Halloween,* written by Ralph and Adelin Linton and published by Henry Schuman, New York.

Outside the church the belief in Halloween as a gathering time for unsanctified as well as sanctified spirits seems to have continued with little change. To the ghosts originally assembled by the Lord of the Dead were added troops of goblins and fairies. This was logical enough, for the fairy folk had their beginnings in an exceedingly ancient, even pre-Celtic, cult of the dead. The fairy host as it first appears in Scottish and Irish legend was not made up of gauzy-winged midgets but of beings larger and more beautiful than men. They were the ghosts of ancient kings and heroes mingled with elder gods. The burial mounds of the Neolithic and Bronze Age folk were their dwellings, and they rode forth on the feast of Samhain to take a scornful look at the feeble folk who kept the land they once ruled. Stunned by the sound of Christian bells and shriveled by holy water, the fairy folk dwindled to "little people," whose only vestige of their ancient state was that they still kept their ancient dwelling places. Even so dazzling a figure of romance as Maeve, the warrior queen of Connacht, survived only as the fragile Queen Mab of the English poets.

Even more characteristic than the inclusion of goblins and fairies in the Halloween customs was the association of the festival with witchcraft. Long after the church had triumphed over organized paganism, country people everywhere in Europe continued their ancient practice of placating local spirits and enhancing fertility by magical rites. Their magic was as much "white" as "black." The parish priests tolerated these doings even if they did not approve of them, and the villagers themselves saw no conflict between them and Christianity. In the later Middle Ages the church began to take a stronger stand against such survivals, and with the Reformation they were classed as heresy.

The result was the emergence of witchcraft as a more or less organized cult in opposition to the church. Much of its ritual was a travesty of Christian rites, but it also incorporated many of the ancient beliefs and practices, among them the ancient sacred days. Halloween became the great witch night. The Prince of Darkness and his cohorts, the witches and warlocks, gathered to mock the church's festival of All Saints by unholy revels of their own. In Germany their meeting place for the Great Sabbath was the mountain called the Brocken; in Sweden, the Blocksberg; in France, the Forest of Ardennes. In Great Britain it seems that any old church, ruined abbey or megalithic monument on a lonely heath would serve.

ON the eve of Samhain the pagan Celts lit bonfires on the hills to welcome the winter season and ward off evil spirits. In dwellings all the cooking fires were extinguished and new ones kindled in token of the new year. The idea that ghosts and spirits fear fire is widespread, and with the rise of the witch cult, fire became the favorite weapon against the powers of darkness. The burning of witches was a rite of purification even more than of punishment.

The peasants of Scotland and Ireland still build fires on the hillsides on Halloween. They also plait their pitchforks with straw, set them afire and wave them aloft to singe the brooms of any witches who may happen to be hovering nearby. The Scandinavian peasants have a similar custom, believing that blazing, straw-laden pitchforks and thrown disks of burning straw will drive the witches back to the Blocksberg, the mountain where the queen of the witches dwells.

While in Catholic countries people go to the churches and the cemeteries on Allhallows, in Scotland and Ireland shreds of the old Druidical mysteries still cling to this holiday and change its essential character. The Scots build great bonfires, and the glow of the flames is reflected in the lochs and lights up the hills. These fires are still called Samhnagan, though they are not lighted in honor of Samhain. The god's survival is in name only. The fires are kindled for

Halloween gaiety and a defiant welcome to the winter season. Some of the old folks may recall that the flames are useful in driving away witches.

On Halloween the Gaelic country folk gather at some hospitable cottage to play the traditional eerie games and have a "social glass of strunt," as Robert Burns puts it in his poem *Halloween,* a treasury of folklore for this holiday. Since the fairies and trolls are abroad this night, as well as the witches and ghosts, the games are usually a form of divination spells. If they are approached with the proper rituals, the spirits can look into the future and help mortals look ahead and know their destinies. There are a great variety of these spells, mostly having to do with love prophecies: burning nuts, sowing hemp, walking downstairs backward with a lighted candle and a mirror, throwing apple peelings over the shoulder, pulling kale and so on.

Because the sportive, superstitious aspects of Halloween that we practice in the U. S. come directly from Scotland and Ireland, the celebration was a late development in this country. The early settlers were predominantly English and Protestant. Although the Church of England recognizes All Saints' Day, the roistering, supernatural Halloween is not an English custom. In England Guy Fawkes Day, celebrated on November 5, substitutes for Halloween. The Pilgrims of course rejected all church holidays, even Christmas. They must have regarded Halloween as popish heresy; surely the pranks and spells of the Gaelic Halloween would have been viewed as traffic with the devil himself.

HALLOWEEN did not find a place on the American calendar of holidays until after the Gaelic people began to arrive on these shores. With them came the Catholic observance of Allhallows and All Souls and the folklore to which still clung shreds of the ancient Vigil of Samhain and the Halloween sports of the fairy folk. These later colonists began the custom of holding gatherings at farmhouses on the night of October 31. Since this was the time when apples and nuts were ripe, these two delicacies were an important feature of such parties. Halloween was often called "Snap Apple Night" or "Nutcrack Night" in pioneer days. The participants played the traditional divination games with nuts on the hearth, ducked for apples, threw apple peelings over their shoulders to determine the initials of their future bridegrooms and indulged in other folk customs from the old country. They also discovered that the American pumpkins were excellent for making jack-o'-lanterns, and carved pumpkin faces became traditional symbols of Halloween.

These gatherings, however, were scattered and regional. It was not until after the great Irish immigration which followed the potato famine in the 1840s that Halloween really became a nationally observed holiday in the U. S. The Irish imagination dwells more on the fantastic and capricious than on the darker powers. In Eire it is the fairies, the Sidhe (pronounced "shee"), rather than the witches and devils, which dominate the folklore. Since the Irish believe that the "little people" are constantly hovering about the homes of mortals and that they are especially active on Halloween, any mischief that occurs on that night can be blamed on them. This is the background for the Halloween vandalism which reached its heights in the late 19th century. In lusty pioneer communities practical jokes were one of the favorite diversions at any time of the year, and Halloween provided splendid opportunity for this form of amusement. Honest householders on the morning of November 1 were very likely to find their wagon on the barn roof, the front gate hanging in a sycamore tree and the outhouse lying on its side. They often said, "The goblins must have done it."

The vandalism has abated considerably in this generation. It has been suggested that the prevalence of indoor plumbing has taken much of the sport out of Halloween. Moreover, the police, in spite of their frequently Irish ancestry, take a dim view of goblins and lay a heavy hand on the real culprit when they can catch him. However, any prudent person will see to it that his car is locked in the garage and his porch furniture stowed away before Halloween night. And he will also have a stock of apples, nuts, candies or pennies on hand to dole out to the oddly dressed midgets, doubling for goblins, who ring his doorbell and demand "trick or treat." Otherwise he may find the next morning that he has soap scrawls on his windows, flour on his front steps and toilet paper garlanding his shrubbery.

OF course witches and their black arts are no longer a menace to the community. Ghosts, aware that no offerings are laid out for them by fearful relatives, haunt their former homes no more on the Day of the Dead. Fairies are found only between covers of brightly illustrated books for children or in Walt Disney cartoons. Despite all this, shreds of old pagan superstitions still cling to all of us. We can still feel a glow of satisfaction when the Halloween spells proclaim that our beloved is true, or that there is a new lover coming into someone's life, though, of course, we don't really believe in such childishness. Still I wonder how many readers could walk alone through a graveyard on Halloween night without feeling a chill of terror down the spine.

Ralph Linton is professor of anthropology at Yale University.

BUSINESS IN MOTION

To our Colleagues in American Business . . .

For several years this space has been used to tell how Revere has collaborated with its customers, to mutual benefit. Now we want to talk about the way our customers can help us, again to mutual benefit. The subject is scrap. This is so important that a goodly number of Revere men, salesmen and others, have been assigned to urge customers to ship back to our mills the scrap generated from our mill products, such as sheet and strip, rod and bar, tube, plate, and so on. Probably few people realize it, but the copper and brass industry obtains about 30% of its metal requirements from scrap. In these days when copper is in such short supply, the importance of adequate supplies of scrap is greater than ever. We need scrap, our industry needs scrap, our country needs it promptly.

Scrap comes from many different sources, and in varying amounts. A company making screw-machine products may find that the finished parts weigh only about 50% as much as the original bar or rod. The turnings are valuable, and should be sold back to the mill. Firms who stamp parts out of strip have been materially helped in many cases by the Revere Technical Advisory Service, which delights in working out specifications as to dimensions in order to minimize the weight of trimmings; nevertheless, such manufacturing operations inevitably produce scrap. Revere needs it. Only by obtaining scrap can Revere, along with the other companies in the copper and brass business, do the utmost possible in filling orders. You see, scrap helps us help you.

In seeking copper and brass scrap we cannot appeal to the general public, nor, for that matter, to the small businesses, important though they are, which have only a few hundred pounds or so to dispose of at a time. Scrap in small amounts is taken by dealers, who perform a valuable service in collecting and sorting it, and making it available in large quantities to the mills. Revere, which ships large tonnages of mill products to important manufacturers, seeks from them in return the scrap that is generated, which runs into big figures of segregated or classified scrap, ready to be melted down and processed so that more tons of finished mill products can be provided.

So Revere, in your own interest, urges you to give some extra thought to the matter of scrap. The more you can help us in this respect, the more we can help you. When a Revere salesman calls and inquires about scrap, may we ask you to give him your cooperation? In fact, we would like to say that it would be in your own interest to give special thought at this time to all kinds of scrap. No matter what materials you buy, the chances are that some portions of them, whether trimmings or rejects, do not find their way into your finished products. Let's all see that everything that can be re-used or re-processed is turned back quickly into the appropriate channels and thus returned to our national sources of supply, for the protection of us all.

REVERE COPPER AND BRASS INCORPORATED
Founded by Paul Revere in 1801
150th YEAR OF SERVICE TO AMERICA
Executive Offices:
230 Park Avenue, New York 17, N. Y.
SEE "MEET THE PRESS" ON NBC TELEVISION EVERY SUNDAY

LIFE IN THE DEPTHS OF A POND

The quiet waters of a small lake are an active universe of living things. On or near the bottom are tiny animals that are related to the whole yet unique in their adaptation to special conditions

by Edward S. Deevey, Jr.

LINSLEY POND near New Haven, Conn., is a typical "reduced" lake. In summer, when its aerated surface waters are too warm and light to be stirred into the depths, the animals of the bottom do largely without oxygen.

THE romantic appeal of oceanography is composed of many things—the heritage of seafaring ancestors who braved the vasty deep alone and unafraid, the lure of the last frontier, the scientific certainty that new and probably fabulous monsters await the next haul of the dredge. Oceanographic expeditions yield sagas or epics, and by contrast the poetry of lakes is so minor as to be almost inaudible. We laugh at the sailor who takes his girl for a row on the lake in the park, and the student of lakes knows that he will dredge his favorite pond a long time before catching anything so exciting as the squid with searchlight eyes or the deep-sea fish that dangles a luminous bait from a built-in fish pole.

The modern naturalist, however, is not content to describe nature's marvels in a spirit of awe. He calls himself an ecologist, and considers that he brings a new viewpoint, and at times a new dimension, to biology. To the ecologist the oceanic abyss, like high mountains, polar regions, hot springs and tar pools, is just one of many places where conditions are so extreme that only marvelously adapted creatures can survive at all. Deep-sea fishes are showy, and their Sunday-supplement oddity helps to raise money for oceanography, which needs it in large quantities. The story of a pond reserves its drama for those who know how to read it, and it is just as well for the progress of ecology that rowboats cost less than oceangoing research vessels.

The life of lakes, though wanting in melodrama, has a quiet charm of its own. But the real advantage in the study of lakes, or limnology, over oceanography lies in its readier approach to fundamental matters belonging uniquely to ecology. These are quantitative matters, involving the amount of life in a given space, and the rate at which the sun's energy is turned into plants and then into animals. In the huge and complex ocean such matters can only dimly be sketched, but in small lakes they can be specified under conditions that can be varied almost at will.

THE depths of the small lake are as peculiar in their way as those of the Atlantic. Not many kinds of things can live in them. Those that can are animals and bacteria, feeding on the steady rain of organic stuff that falls from shallow water. Upstairs is a world of light and oxygen, dominated by green plants. Below is a sunless and sometimes airless region, ideal for creatures that can stand it but no place for weaklings. A few species of midge larvae, aquatic earthworms, flatworms and roundworms, a clam as big as a pea—this is almost the whole list. And not all of them can live in the same lake: Lake Mendota, near Madison, Wis., has only five deep-water species big enough to stay in a fine net when the mud is washed out.

The number of species in a lake is not limited by a lack of food; there is plenty of it. The mud on the bottom of lakes is nutritious; most residents of the mud eat it directly, as Hansel and Gretel ate the witch's house. The drawback is the lack of oxygen. The gas must be dissolved in the water, of course, for no animal can extract the 0 from $H_2 0$.

Oxygen is added to lakes by photosynthesis, which is mainly confined to the surface. Turbulence then mixes the oxygen-rich surface water with that of the depths. Heat is also added by turbulent mixing. Water, like most liquids, becomes lighter as it is warmed, but its lightness increases disproportionately. As a result, in lakes deeper than about 10 meters, the surface water is so light by early summer that no amount of wind can mix it into the denser water at the bottom. Therefore no oxygen can reach the depths until fall, when the surface cools. During the long summer stagnation the organic matter that falls to the bottom is decomposed by oxidation, and, like a closed tourist cabin with a gas heater, the deep water is robbed of its oxygen.

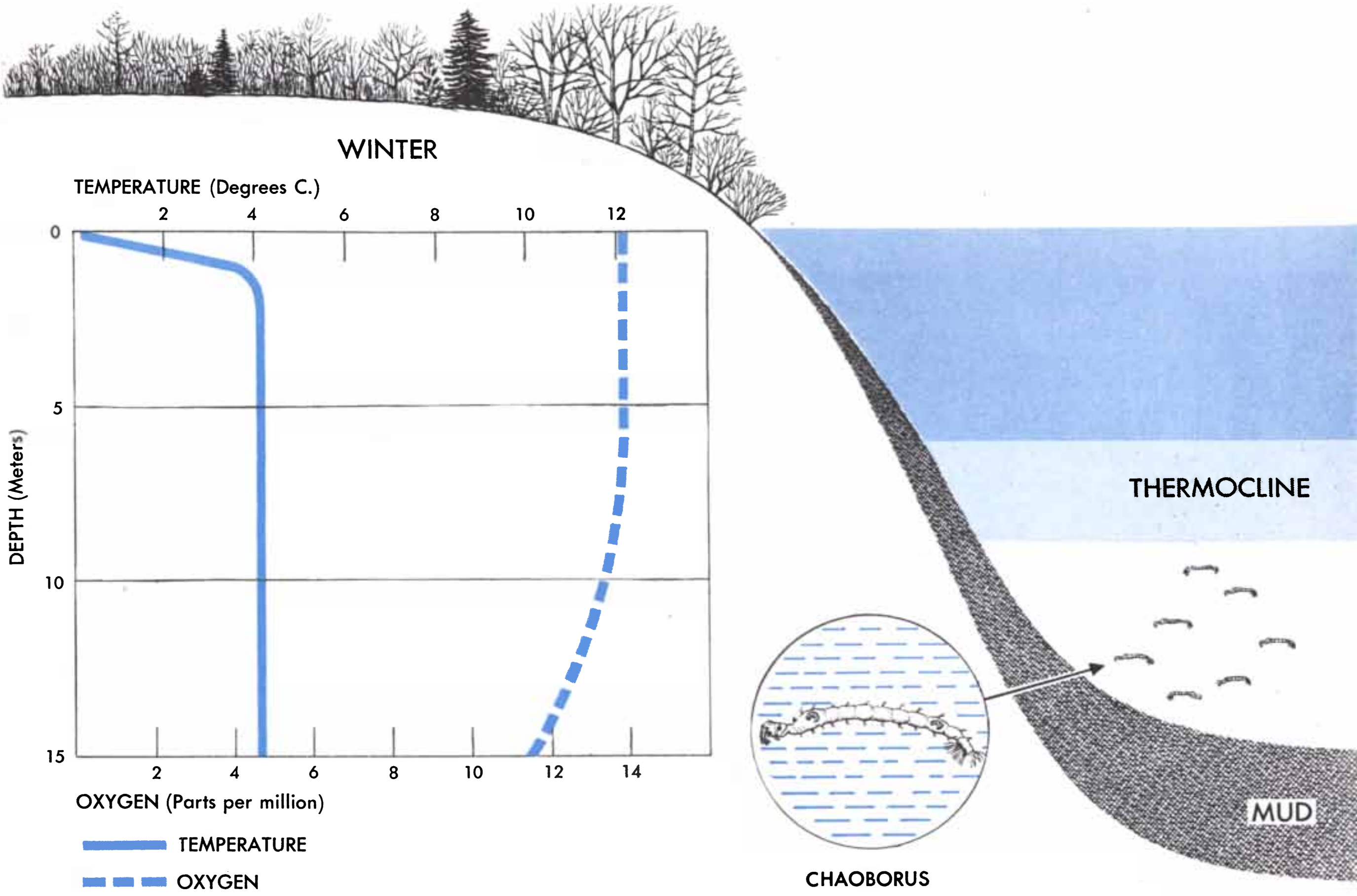
After the organic rain has settled to the bottom, its further oxidation is slowed; it is usually buried long before it has been completely consumed. Oxidation and reduction are two sides of the same coin; if something is oxidized, something else must be reduced. After all the free oxygen is reduced, the incompletely oxidized material remains as a potential reducing agent. Before the end of stagnation, reducing conditions may spread from the mud into the overlying water, and the products of incomplete oxidation leak out: ammonia, methane, ferrous iron and hydrogen sulfide. Like a great sponge, the mud lies ready to soak up oxygen when circulation admits it. This is a strange environment for an animal, for some of the substances are poisonous and all of them compete with animals for oxygen.

NOT ALL lakes get themselves into such a state. The balance between oxidizing and reducing conditions is a delicate one. In two lakes of the same area and volume, the one with more plankton—the small plants and animals that dwell at the surface—will have less oxygen in deep water by the end of summer, for it is the plankton that produces most of the organic debris. In two lakes having the same amount of plankton, the one with the smaller volume of deep water will run out of oxygen sooner, since the reservoir is smaller. For a fish such as a trout, which is as finicky about its environment as it is about a dry fly, a summer in a lake poses a dilemma: the surface waters are too hot, but to retreat into the cool depths is to run the risk of suffocation. Under somewhat similar circumstances, in the swamps of the Paleozoic Era, some fish stepped out on land for a breath of air.

As land-dwelling descendants of one of those Paleozoic fishes, we live in an oxidized world, and we are bewildered when we study the bottom of a reduced lake and find any animals there at all. The mystery is not cleared up yet, but some progress has been made. Best known of the bottom animals of such lakes is the red larva of the midge *Chironomus.* A typical reduced lake, Linsley Pond near New Haven, Conn., has an average of 35 grams of animals per square meter, more than half of which consists of this insect.

The most striking thing about *Chironomus* is its red color, but this has proved to be a red herring. The pigment is hemoglobin, and the blood that contains it is saturated with oxygen at all ordinary oxygen pressures. At very low pressures the hemoglobin comes into play, and permits the animal to extract the last remnant of oxygen from its environment. But as a storehouse for oxygen the oxidized hemoglobin is inadequate for more than a few minutes' respiration, whereas the animals can live for four months without oxygen. Moreover, there is a related midge larva, *Tanytarsus,* that lives on the bottom of lakes that never run out of oxygen, and it too is red, or at least pink. Barbara Walshe of the University of London, who has studied both midges in the laboratory, reports that "the hemoglobin of *Tanytarsus* functions by transporting to the tissues an inadequate amount of oxygen, at an external oxygen pressure which in any case is probably ultimately lethal." This is a British way of saying that hemoglobin is not the answer.

Since most animals lack the ability to live without oxygen, the few that have this ability must have acquired it after the evolution of animals. This suggests a clue, for we may surmise that *Chironomus* has made an improvement on some basic animal patent. Muscle contraction is one of these. Its source of energy is the oxidation of carbohydrate. Free oxygen is necessary, not for the contraction itself, but for the removal of such toxic products of incomplete combustion as lactic acid, and for the restoration of the muscle to its contractile state. Muscular work in the absence of oxygen leads to lactic-acid poisoning, but most active vertebrates, especially diving animals such as seals and loons, have devices for holding lactic acid in their muscles during intense activity; the human sprinter performs the same trick. The metabolic poisons are not released into the blood and carried to the lungs until normal breathing is once more possible, and the accumulated oxygen debt can be paid off quickly and safely. Life without oxygen is called anaerobic, but



WINTER AND SUMMER CONDITIONS in Linsley Pond are shown on these two pages. In the center is a cross section of the lake in summer, the vertical scale of which is exaggerated. The epilimnion, or surface layer, is warm and aerated because it circulates freely. The hypolimnion, or bottom layer, is cold and anaerobic because it does not circulate in summer. The thermocline is the zone in which the warm temperatures of

we have not described anaerobic respiration. It is, however, an approach to it. If a way can be found for getting rid of the waste products of anaerobic oxidation, life without oxygen becomes practical. From the standpoint of chemical energy it is an expensive process, comparable to throwing out four-fifths of the coal with the ashes from the furnace, but there are places where there is enough fuel to make it worth while.

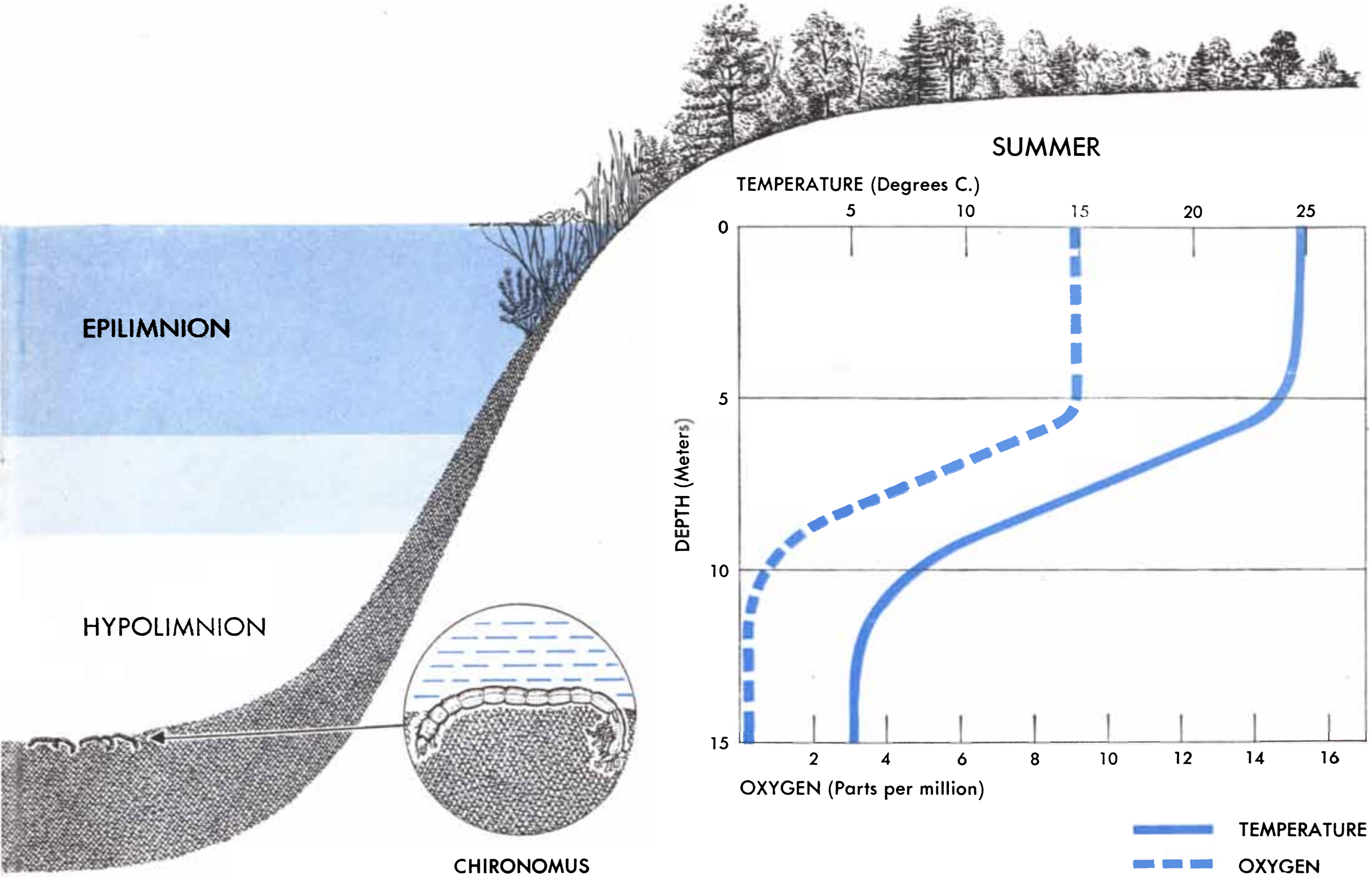
As it happens, *Chironomus* is one of the few higher animals, and probably the only non-parasite, in which this kind of metabolism has been proved to operate. When Miss Walshe placed *Chironomus* larvae in a closed vessel, they simply excreted their lactic acid into it. And when air was admitted to the vessel the oxygen debt of the larvae was not repaid. If it is as simple as that, why have other animals not hit on the same expedient? Probably because, being animals, they arose after the plants had created an oxidized environment.

If *Chironomus* is capable of remarkable feats of chemistry, physics is not neglected by the personnel of the lake bottom. The phantom midge larva, *Chaoborus,* is a daily commuter to this environment, spending the daylight hours on the bottom and rising to the surface at night. Vertical migration is not unusual among members of the plankton, and the glassily transparent *Chaoborus* has probably acquired the habit in order to stalk the shrimplike copepods on which it preys. What is unusual about the migration is the speed with which it occurs: 20 meters per hour in Lake Mendota. The animal is also peculiar in that it contains two pairs of gas bubbles. These belong to the tracheal respiratory system of all insects, but in *Chaoborus* the system has no external openings. Like the tracheae, the bubbles have stiff walls of chitin. Unlike them, they are covered with expansible pigment cells of the kind responsible for the quick color changes of chameleons and flatfish. The pigment cells respond to light and temperature, but their function is unknown. What is certain is that the gas bubbles help the animal adjust its buoyancy according to the pressure of the water, and in fact no animal with enclosed gas chambers could move rapidly through two atmospheres' difference in hydrostatic pressure if some such equilibration were not provided. The question is how is it done?

A suggestion by the late Danish physiologist August Krogh, that liquid is pumped in and out of the bubbles as in the ballast tanks of a submarine, has had to be ruled out, for the bubbles contain no liquid. The bubbles actually change volume to compensate for pressure changes, perhaps by altering the elasticity of their walls; this is a trick the early balloonists would have envied and it is hard to say how *Chaoborus* could bring it off.

What is the gas? Air, say some workers. But here is another puzzle; *Chaoborus* hatches from the egg on the bottom of the lake, and fills its gas chambers out of contact with air. The swim bladders of fish contain oxygen, carbon dioxide and nitrogen, but it is a mixture quite different from air. The atmosphere as we know it has been evolving for two billion years, and no animal is likely to secrete it ready-made.

Questions like these belong to physiology, and ecologists can claim no credit for originality in raising them; they merely ask that physiology be taken back to nature. Ecology's new dimension



the epilimnion drop rapidly to the cold ones of the hypolimnion. The two diagrams at the left and right have the same scale of depth as the cross section. The diagram at the left plots the temperature and oxygen content of the lake when it is covered with ice. The diagram at the right does the same for the summer. At left center is *Chaoborus*, a midge larva that rises and sinks. At right center is *Chironomus*, another larva.

comes in when we ask questions about the numbers and masses of organisms. Weights are harder to measure than numbers, but they make for sounder comparisons. That figure of 35 grams of deep-water bottom animals under a square meter of Linsley Pond—is it high or low?

BOTTOM animals are fish food, and hundreds of lakes have been studied by limnologists, partly for fishing reasons. Lake Mendota has more bottom animals than Linsley Pond, 47 grams per square meter, but both lakes are well above the average; only a handful show more than 10 grams. As crops go, the deeper bottoms of lakes cannot compete with cornfields as sources of human food, and they yield only a tenth to a fifth as much organic matter as the plankton does. But no one expects animal crops to measure up to plant crops, and it is interesting to find that mud bottoms in deep water support about as much animal protoplasm as a cow pasture or a well-fertilized fish pond.

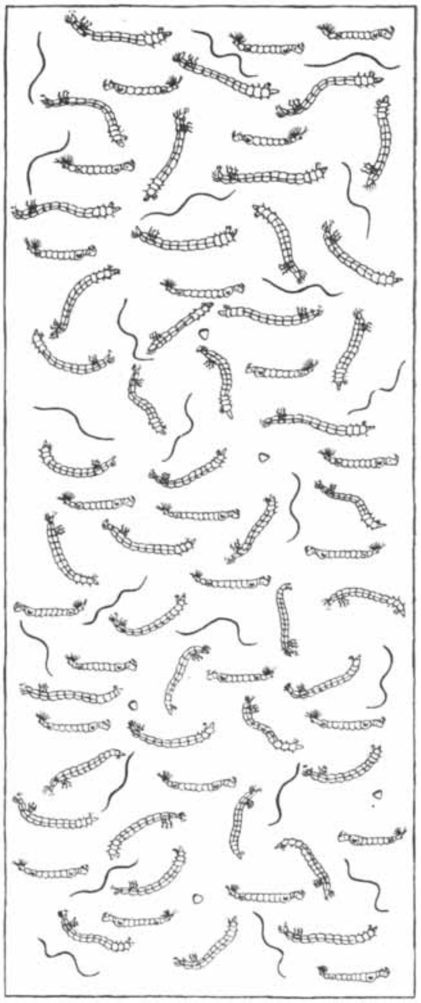
The principle underlying such comparisons has been obvious for many years. It finds one expression in the pyramid of numbers, which will always be associated with the name of Charles Elton of Oxford University. Rabbits and other herbivores live on surplus energy produced by plants, while the herbivores in turn support foxes and other carnivores by unwillingly diverting some of their energy to them. As one goes up a typical food chain, as from plant lice to spiders to songbirds to hawks, the numbers of animals found on an area become progressively smaller; a chart of the numbers looks like a pyramid. The individual carnivores become larger, however, and the comparison is clouded further by the different rates at which the members of the food chain reproduce their numbers. The first serious attempt to cut through the confusion, and to examine all the food chains of a community in terms of rates of production of mass or of energy per unit area, was made in Cedar Bog Lake, near Minneapolis, Minn., by the late Raymond Lindeman.

Lindeman's ingenious calculations suggest that the vegetation of the lake, including the algae of the plankton, converts the sun's energy into plant substance with an efficiency of about .05 per cent. This seems low, but cornfields do no better than lakes as photosynthetic machines, and forests may do worse. By adding up all the rates of production for herbivores, including plankton crustaceans as well as *Chironomus,* and dividing by the rate of production of plant energy under the same area of lake surface, Lindeman found an efficiency of about 10 per cent. He also concluded that carnivores extract energy from herbivores with a higher efficiency, around 20 per cent. Secondary carnivores, animals that eat other carnivores, are probably still more efficient in utilizing the tiny fraction of energy that reaches the top of the pyramid.

Although *Chironomus* is classed as a herbivore, belonging to a link in a food chain whose over-all efficiency is about 10 per cent, its own efficiency on an areal basis is only about a tenth as great. Part of the trouble may be that its anaerobic metabolism is biochemically an inefficient process. More probably it merely means that bottom-dwelling herbivores get short rations compared with the herbivores of the plankton. Before the organic stuff reaches the bottom it has been partly decomposed, and

INDEX OF ADVERTISERS

OCTOBER 1951



SAMPLE OF MUD 225 square centimeters in area from the bottom of Esrom Lake in Denmark contains 43 *Chironomus*, 24 *Chaoborus*, 22 *Oligochaeta*, 5 *Pisidium* (pea clams).

some of the nourishment is fed back into the plankton by the circulation of the lake water. The deeper the lake, the greater the fraction of plant production that can be thus cycled through the plankton, and the less there is left for bottom animals.

THE fact remains that the mud of lakes like Linsley Pond yields about as big a crop of animals as good pasture land does, whereas the production of such fish as pike and lake trout, two or three times farther removed from the base of their food pyramid, is infinitely smaller. It is clear that the management of a lake for secondary carnivores is an uneconomic enterprise, comparable to raising peacocks' tongues. However, it is an enterprise that will probably continue until man finds it as pleasant to devour plankton or *Chironomus* as trout.

Edward S. Deevey, Jr., is assistant professor of zoology at Yale University.

New! BAUSCH & LOMB Dynoptic LABROSCOPES

THE WORLD'S FINEST LABORATORY MICROSCOPES

Set higher standards for comfort, accuracy and speed in microscopy with new "Years-Ahead" advanced design features.

● New *Dua-rol* LOW POSITION Ball-Bearing and Roller Fine Adjustment—critical focus, easier and faster; less wear, longer life. New *Roto-sphere* BALL-BEARING Nosepiece—and most accurate parcentricity and smoothest rotation ever.

New Mechanical Stage with LOW POSITION Controls for comfortable operation; 10X Achromatic Objective; New type Variable Focus Condenser for low-cost models; New attachable Integral Illuminator. AND—many other new and service-proved advantages exclusive with or pioneered by Bausch & Lomb . . . further proof that *the world's finest instruments are made in America—by Bausch & Lomb.*

Write for a demonstration and for complete information on this new line of microscopes. Bausch & Lomb Optical Co., 781-10 St. Paul St., Rochester 2, N. Y.

CLIP AND MAIL THIS COUPON TODAY

BAUSCH & LOMB OPTICAL CO.
781-10 St. Paul St., Rochester 2, N.Y.
Please send me complete information on the new B&L *Dynoptic* Labroscopes.

☐ I would like a demonstration.

NAME____________________
SCHOOL OR FIRM________________
ADDRESS____________________
CITY____________STATE________

What GENERAL ELECTRIC People Are Saying

A. J. NERAD

Research Laboratory

Task Of Appliances: Looking at the entire field of products which we call domestic appliances, it appears that they have undertaken and are doing a remarkable task. We are in a new kind of world in which domestic service has vanished with only a few remaining exceptions to prove this a rule. In the early history the purpose of the appliances was to improve the quality of domestic work and make toil somewhat less arduous. Now they have the added purpose of saving domestic labor to a high degree. It is amazing to consider how much has been accomplished in this direction pleasantly and advantageously.

The gradual injection of controls and integrators into the appliances has uniquely given them the equivalent of a thinking apparatus. By ordinary development processes. results have been achieved which appear as results of wizardry. The appliances not only think but act accordingly. Thus a dishwasher measures a given quantity of water and immediately at the right moment closes the valve. Clothes washers are in use which do a large number of complicated tasks in proper sequence. No human could follow as simply or quickly the electric blanket control in its compensation for changes in room temperature, for it would require adding or taking off blankets at a rate that is too trying and all too difficult to follow.

There are some unique advantages in this revolution in the home. You can't hire one-twentieth of a domestic servant, but you can obtain appliances one at a time. It is unthinkable to have domestic help 24 hours a day and seven days a week in these times, nor is it possible to suddenly obtain such help at any instant. Even in the good old days this could not be accomplished, but our present appliances are ready at any instant for use, and we need not have the slightest qualm at any time in their use. Some of them, like the oil and gas furnace controls, receive their instructions long ahead for long periods of time, and with less fault or omission than human beings they do the tasks once required by people in the house.

The appliances have taken upon themselves a very serious part in our life, indeed. It is thus easy to forecast that, in the light of future developments, theirs will be a firm place in the household. The appliances are not made yet which can take the place of a baby sitter, but some of them make the baby sitter's task less difficult and more pleasant. The future will also find that, to fill the lack of an appliance which will not only prepare the meal but plan it, is an engaging problem. It does not require too much dreaming to visualize a computer which turns out the most varied, healthiest and most economic menu. Even without turning to the achievements of the future, it is easy to see why there has been such tremendous growth in the domestic appliance industry.

A.I.E.E. Conference
Columbus, Ohio
May 15, 1951

★

C. P. HAYES
H. R. GOULD

Apparatus Department

Fluorescent Lamp Noise: The past two decades have seen tremendous strides toward quieting of nearly all types of equipment such as the automobile, the clock, and the electric refrigerator. However, the introduction of the fluorescent lamp brought an appreciable *increase* in noise to lighting. . . . This made the job of the ballast designer a difficult one because, compared to other electromagnetic devices, the ballast was relatively quiet; but in low-noise-level locations, the ballast was an irritating source of noise. . . .

Noise generated by the ballast usually is greatly amplified by the lighting fixture in which it is used. . . . The noise generated by the energy source within the ballast is transmitted to the fixture by mechanical vibration of the ballast surfaces in contact with the fixture and by airborne noise which impinges on the fixture surfaces. To evaluate completely the noise characteristics of a fluorescent ballast, both components which contribute to fixture noise must be considered. If any great progress in noise reduction is to be made, a method of measurement which will evaluate these components certainly is indispensable. . . .

The primary purpose of developing a ballast-noise measurement system was to obtain a realistic noise-quality number which would define the noise characteristics of any ballast. . . . Experience with test equipment indicates that, with the variables of mounting, heating, and fluorescent lamps closely controlled, it is possible to obtain reproducible noise data. . . . It is believed that this measuring system has been developed far enough to be considered by others who are concerned with the problems of ballast noise and its measurement.

General Electric Review
June, 1951

★

A. F. DICKERSON

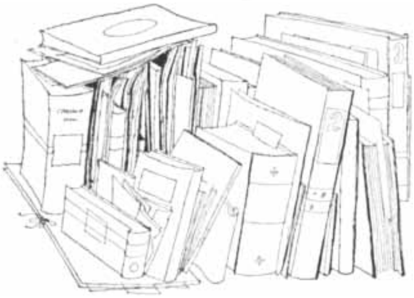
Apparatus Department

Traffic Fatalities: At least half of all night traffic fatalities on our dangerous streets and highways could be prevented by the proper use of street lighting. From five to ten times as many traffic fatalities occur at night as in the daytime on some of our most dangerous streets. This night accident rate will undoubtedly rise, because of the greater traffic which will be a direct result of increased defense production and military training.

Lynn, Massachusetts
April 6, 1951

You can put your confidence in—

GENERAL ELECTRIC



BOOKS

Operations research as an example of the contemporary evolution of science

by J. Bronowski

Methods of Operations Research, by Philip M. Morse and George E. Kimball. The Technology Press of the Massachusetts Institute of Technology and John Wiley & Sons, Inc. ($4.00).

TWO great wars have now shown the fearsome success of science when it bends its mind to destruction. In the first war the part played by science was largely technical, and the great showpiece of science in the second war, the development of the atomic bomb, was again the achievement of specialists. But during the second war there was also a great deal of lively and intelligent scientific work of a more general kind which did not lie in any well-defined field of academic study, and had little to do with technical skill in manipulating the formal concepts of physics or mathematics or biochemistry. Scientists from all fields met in this no man's land of informal problems, none of which had ever appeared on an examination paper, and they had a wonderful time talking to the man with the gun and the General, doing sums on the back of military orders and generally persuading themselves that destiny had plucked them from the campus and overnight made them men of action. It was an inspiring life, and it is not surprising that it should have inspired much swift and striking success. When the war ended, those who had lived this life were naturally loath to think it nothing but an uncharacteristic adventure that was now over once and for all, and many of them have since tried to find some substance and common ground in all that flurry of warlike thinking. They have at any rate found a name, operations research, to which a good deal of discussion and writing has since been devoted. Little of what has been written has made the subject more solid or coherent. *Methods of Operations Research*, by Philip M. Morse and George E. Kimball, is without challenge much the best that operations research has called forth.

Before I turn to the book I should like to unravel the odd strands that went into the wartime success of operations research. In the first place every war develops many fine amateur warmakers. They rise steeply in the armed services, in the national administration and equally in the twilit borders of command where the scientist is invited to speak his word of advice. The British Ambassador in Washington, Sir Oliver Franks, was a professor of philosophy until, under the pressure of war, the British Civil Service made room for him. And the speed with which he rose through the Service startled his friends quite as much as scientists were startled by the warlike skill shown by some of the pupils of the great physicist Lord Rutherford. When almost every man in a country changes his job, a great many of them will turn out to be unexpectedly good at their new work; this process of shaking up will be particularly successful when the failures can always fall back on their old university jobs. In this respect, then, the success of scientists in military councils is merely the outcome of a process of systematic shuffling which has been equally successful in bringing to the top all kinds of amateur soldiers and diplomats and strategists.

What these amateurs have in common is less the skill to do better what the professionals had already been doing than the recognition of what the professionals had left undone. I know the permanent head of one British Ministry who was a university don before the last war; he is a most successful civil servant because he knows how civil servants think but he does not think like them; the second of these qualities is easier come by but less useful than the first. So one contribution of scientists in military commands was certainly that they saw command problems in quite unfamiliar terms. They thought in a new language, and the grammatical structure of this language (which is always a form of analysis of what is said or thought in the language) was different enough to give the problems a new twist and weight. We have here gone a step beyond the shuffling process of picking winners, but I have not implied that the step has anything to do with science. Some first-class work was done in military intelligence during the war by historians as well as by mathematicians. The only trick that they shared was the habit of translating military jargon into their own languages.

But what of the final step? What is it specifically that the scientist and no one else brought to the problems of military decision? Biologists and engineers, chemists and entomologists and, to my knowledge, at least one paleontologist, did indeed contribute one quality that is written large in all accounts of operations research. The quality was the scientific outlook, which these men brought with them like an aura. Inflated as its claims often are, I myself learned more about that outlook from the young men who put it into clumsy sentences in operations rooms than I ever learned about it in a philosophy class. These men tried to think logically and quantitatively, but neither of these is really as important as the fact that they tried to act empirically. A war or a battle cannot be repeated; in a sense even a mission or a sortie is unique. At any rate there is always a good reason why whatever went wrong with the operation is held to be quite special and accidental, and why it will be quite all right to set about the job tomorrow exactly as we did yesterday. This outlook, which has been called "fighting the last war," is said to be characteristic of military men, but it is not peculiar to them. It is not even peculiar to nonscientists. Yet it is rarer among young scientists than among those with a different training. A war or a battle, a mission or a sortie, none is repeatable and none is an experiment. Yet the young scientists brought to them the conviction that in them and nowhere else must be found the empirical evidence for the rightness or wrongness of the assumptions and underlying strategy by which war is made. The passion of these men was to trace in operations involving life and death the tough skeleton of experimental truth.

Here we come to the crux of what is new for academic science in the approach of the operations research worker. Since the turn of the century the biological and social sciences have tended to turn away from the classical laboratory approach in which the variables of a problem are isolated one by one; instead these sciences accept the variations of nature and make the best of them. For this purpose the classical mathematics of exact quantities has proved useless, and as a consequence workers in Great Britain, the U. S. and the U. S. S. R. have built the beautiful mathematics of probability. But this way of taking all nature as an experiment is still a stranger in most university departments and a positive heretic in the schools. As a result most scientists who went to military commands had no idea of how to conduct an experiment over which they had no control, and no notion that there were whole branches of science, from the study of children's intelligence to the location of thunderstorms, in which their problems were everyday problems. Indeed, most of them remain to this day puzzled that biologists and even some sociologists turned out to be so good at operations research. They feel this to be some kind of slur on the so-called exact sciences.

Of course the point is that operations research is not an exact science. It is the art of exploiting the grandiose experiments of nature and high commands; it is therefore the epitome of the inexact sciences. This is one reason why operations research was so raffishly attractive to wartime fugitives from the campus, and why the influence on the campus of the liaison has been so admirable.

The exact sciences always belong to the war before the last. The scientists of today, in my opinion, are the *sans-culottes* of a second scientific revolution in which the prim methods of the laboratory are being conquered by a new and more thoroughgoing empiricism. The notion of isolating an experiment in a box and ticking off the variables that matter neatly on one's fingers is 50 years out of date. Today almost all research is unitary, and its field of inquiry is as wide as our experience. I cannot disregard the influence of the weather on the closing prices in the Chicago wheat pit; I can at most find it below the threshold of significance reached by other factors, and this only by measuring it on the yardstick of the residual variation within the data. The controlled laboratory experiment is dying, and in its place science draws its breath from the statistical analysis of the everyday variation in nature.

All this the modest young men of operations research discovered for themselves. They saw it vaguely and they did not put it very coherently, but they did discover that, scientific method or not, they were doing something which they had not been taught and which to them was new. It is not as new to those who have watched the long retreat of laboratory science, and the growth of the essentially new methods of statistical mathematics. In teaching these methods, and in broadcasting the deeper concepts of probability reasoning, the operations research units did an important job in scientific education. To this day examples from military operations remain the most vivid material for showing the play of probabilities, particularly in the field of small samples, and papers on operations research illustrate this difficult theory more cogently than many textbooks.

Professors Morse and Kimball bear this out by giving more space to the mathematics of probability than to any other single subject. For the rest what they have to say is largely meant to help the man of sense reduce the formidable scale of experiment in operations to something more modest and quantitative. The authors rightly give a good deal of space to discussions which turn on the proper measure of operational effectiveness. Their book is full of wise practical hints of this kind: that it usually pays to improve the performance of the worst in the unit, to watch what is left undone rather than what is done with equipment, to exploit the gains to be had from training and refresher courses, not to overrate the enemy's countermeasures against good equipment. In general it will be noticed that these are all really theorems about symmetrical matching. They seek to balance the level and variability of one part of a performance with another—usually the human part with the mechanical. They are in fact typical discoveries, new to the laboratory scientist, in a field where performance is enormously variable and subject to frightening errors of prediction.

All this the book does better by precept and encouragement than by theory, and does best of all by illustration. It is indeed the handsomest collection of examples of operations research that we have had: U-boat spotting, the setting of depth charges, the Battle of the Atlantic, the acoustic torpedo, bomb patterns and the ganging-up of tanks—they are all here. After this lapse of time most of them have a slightly mummified look, and there are moments when one wonders whether the old soldiers of operations research are ever going to stop counting their medals. But they are all nice stories; none of them is dull. The only doubt is whether methods that were invented in the heat of the moment by quick-witted amateurs can be taught at this pedestrian recall to their professional replacements.

Like most books of its kind, *Methods of Operations Research* lays too much stress on what are essentially physical examples. The important work of operations research in medicine and the study of casualties is not touched on. There are some perfunctory passages about the peacetime uses of operations research, but they are not helpful in practice, and in their theory they miss the wider implications of applying the scientific method in the field. The most important topic that is left unexplored in this and other books is the general analysis of small samples subject to large fluctuations—particularly in "contagious" and "trigger" sequences such as traffic jams. Probably the greatest contribution to research in operations, whether the operations are of war or peacetime industry, remains to be made here.

Is there then a future for operations research today, either in industry or in war? I doubt it; at least, I doubt whether it can again be useful in the simple sense of the last war and of this book. The heroic age is over; and, dropping with a sigh the glamour and the heady sense of power, we have to face the recognition that the field of opportunity will never again be quite so blank, so simple and so lavish. What was new and speculative on the battlefield turns out, in the practical affairs of industry, to become only a painstaking combination of cost accounting, job analysis, time and motion study and the general integration of plant flow. There is an extension of this to the larger economics of whole industries and nations, but it is hardly likely to be rewarding to first-rate scientists, and calls at bottom for the immense educational task of interesting economists and administrators in the mathematics of differentials and of prediction.

Nor is the art of war likely to offer again such a creamy surface to skim. The easy successes have been scored; the simple mistakes which they put right are understood and should not be made again. The analysis of operations must expect now to go a good deal deeper and to be a great deal more like research. Operations research has done its major work, and it turns out to have been a piece of education—the education of scientists and warriors in a new empiricism.

J. Bronowski is Director of the Central Research Establishment of the British National Coal Board.

MIRACLE AT KITTY HAWK: THE LETTERS OF WILBUR AND ORVILLE WRIGHT, edited by Fred C. Kelly. Farrar, Straus & Young, Inc. ($6.00). THE WRIGHT BROTHERS, by Fred C. Kelly. Farrar, Straus & Young, Inc. ($5.00). No matter how often told, the story of the epochal flight on the North Carolina sand dunes on December 17, 1903, and of the work of the two brothers who made it possible does not lose its fascination. Of the more than 10,000 letters by the Wrights on file in the Manuscript Division of the Library of Congress, Mr. Kelly has selected about 600, mainly written by Wilbur, during the years 1900-1910. Together with a number of useful annotations, these convey an extraordinarily vivid and interesting picture of the Wright brothers, their relations with other aviation pioneers, their experiences at Kitty Hawk and Dayton in making their invention, and in New York, Washington, Paris, London and Berlin in making money out of it. The letters make clear how painstakingly the groundwork of successful power flight was laid. They show the brilliance of the Wrights' experiments, the sureness of their instincts, their self-confidence and stubbornness of purpose, the deep bond of affection and understanding which enabled them to merge separate talents into a single creative faculty. The Wright brothers, one is tempted to think, possessed a peculiarly American genius. They had the ability, with little formal

CONCERT HALL SOCIETY
INVITES YOU TO ACCEPT THIS
Special Introductory Offer
..THIS LONG-PLAYING RECORD
Only $1.00
(WORTH $4.50 RETAIL)

BEETHOVEN Piano Concerto No. 2 in B-flat
OR
MOZART Piano Concerto No. 11 in F

HERE is an extraordinary opportunity for music lovers! We will send you your choice of either one of these delightful concertos, each superbly performed IN FULL by the brilliant pianist Artur Balsam and the Concert Hall Symphony Orchestra. Both are high fidelity, Long-Playing (33⅓ R.P.M.) recordings—yet you may have either one for only one dollar!

We make this special offer to demonstrate the remarkable quality of Concert Hall high-fidelity recordings. We will also send our free brochure telling how you can obtain our new series of recordings available nowhere else at any price!

Membership Limited to 3000

Only 3,000 members can own these limited-edition recordings; and right now only 565 subscriptions are still available. The whole interesting story is told in our free brochure, which we will send with the LONG-PLAYING record described above. Simply enclose one dollar with the coupon. If not delighted with the record, return it in five days and your dollar will be cheerfully refunded.

Concert Hall Society, Inc. **A4610**
507 West 56th St., New York 19, N. Y.

I enclose $1. Please send me the high fidelity LONG-PLAYING record checked below. If not delighted, I may return it in 5 days for refund of my dollar. Also send, free, your brochure describing the new 1952 series of Limited Edition recordings.

BEETHOVEN ☐ ☐ **MOZART**

(This special offer good only in U.S.A. and Canada)

Name..
(Please Print Plainly)
Address..
City..........Zone ....State............

A distinguished analysis of our economic resources by
WASSILY W. LEONTIEF
Professor of Economics, Harvard University, Director of the Harvard Economic Research Project

The Structure of the American Economy

A study that presents the application of the general equilibrium theory to the empirical analysis of the structure of our economy in 1919, 1929 and 1939.

The analysis is presented in terms of industrial input-output distribution tables. These tables make it possible to examine in detail the interaction between inputs and outputs at any one time under given economic and technical conditions.

"A new and usable tool for describing the American economic scene . . . Particularly valuable for those readers involved with marketing problems in industry, concerned with where they should sell what proportion of their production. The production man, too, will find it of value in analyzing sources of supply and possible alternates."—*Modern Industry*

$5.75 at all bookstores

OXFORD UNIVERSITY PRESS
114 Fifth Ave., N. Y. 11

New Idea Makes You a Better Speaker—Fast
Improves Your Speaking Voice in One Evening

PUBLIC speaking will no longer be a dreaded ordeal—it will be a golden opportunity to impress your personality upon your listeners; to win approval and applause; to increase your prestige and your stature; to advance yourself in position and earning power.

Sensational Results PROVED

Now, in the privacy and convenience of your own home you can listen to "living voice" demonstrations of the seven basic techniques of effective speaking, with their variations and combinations to fit every occasion. That is the new and revolutionary idea behind the just-released Funk & Wagnalls TRAINING COURSE IN EFFECTIVE SPEAKING—a course that produces results never before possible—that improves your speaking ability so spectacularly and quickly you will be amazed.

FREE—Dramatizing Your Voice

Send now for this absorbing booklet containing valuable hints for improving your speaking ability—a revealing Self-Analysis Chart—Test Exercise with "Sound-Track" Markings and details on how to obtain the new Funk & Wagnalls Training Course in Effective Speaking. No cost or obligation. Write or mail coupon to:

FUNK & WAGNALLS CO., Dept. SC-1
New York 10, N. Y.

FUNK & WAGNALLS CO., Dept. SC-1
153 East 24th St., New York 10, N. Y.
Without cost or obligation to me, send the free booklet, "Dramatizing Your Voice". (No salesman will call.)
Name..
Address..
Town or City..........................Zone........State..........

© 1951 SCIENTIFIC AMERICAN, INC

training, to delve into theory, to take from it precisely what was needed for practical ends, to build their engine skillfully and with a marvelous eye for essentials, and to exploit their accomplishment fully for their own benefit, yet to the advantage of society. Neither the letters nor the revised edition of Kelly's "authorized" biography entirely settle the vexing questions of how much the Wrights owed their predecessors for certain basic ideas of flight control and what led to the deterioration of their relations with Octave Chanute. As the Wrights grew successful they were increasingly embroiled in disputes, became more suspicious, resentful and withdrawn. This much is plain from the letters, as is the fact that attempts were made repeatedly by vindictive men to belittle their invention, and by more practical rascals to deprive them of its fruits. But the letters give only one side; Mr. Kelly, a close friend of Orville Wright, does not really give the other. What the publishers are pleased to call a "revised edition" of his biography is almost indistinguishable from the original, and the author does not help matters by failing to add even a prefatory note telling what was changed or added.

Organization and Pathology of Thought: Selected Sources, translation and commentary by David Rapaport. Columbia University Press ($10.00). As a topic of psychological investigation, thinking, for all its alleged prominence in human behavior, has been relatively neglected in this country. Such studies of thinking as are done usually concern limited aspects of the phenomenon, and the methods of investigation have shown few major changes in the past several decades. To broaden the scope of knowledge about thinking and to encourage the use of promising techniques of inquiry, Dr. Rapaport, formerly director of research at the Menninger Foundation, has reprinted in this volume a number of German and French contributions that are not readily accessible to American scholars. Thinking disturbances, as they are observed in schizophrenia, organic psychoses, daydreams and hypnosis, as well as normal thought, are treated. This is a valuable source book, and its value lies not only in the selections it contains but also in the perceptive and extensive comments made throughout by the editor.

The Origin of the Earth, by W. M. Smart. Cambridge University Press ($2.75). A popular survey of the contributions of astronomy, physics, chemistry and biology to the answers to three questions: What is the earth's parentage? How old is the earth? How was the earth formed, and the solar system itself? Professor Smart has based his work on lectures delivered to soldiers during the war, and has had well in mind the requirements and limitations of an average audience; he has succeeded in conveying in a brief compass an astonishing amount of accurate information on an enthralling subject. A solid and readable book, by far the best of the recent works in its sphere.

Everyman's Encyclopaedia, edited by Athelstan Ridgway. The Macmillan Company ($27.50). The third edition of this excellent work has been substantially revised and enlarged. It has nine million words and 2,500 illustrations; each of its 12 volumes, printed on thin but opaque paper, is compact; the type is small but wholly legible. *Everyman's* is fully up to date and is strongest in its articles on science, history, philosophy, biography, politics, the arts and literature. One is not always able to find in it, as in *The Columbia Encyclopedia,* with which it is in a sense comparable, the latest details about contemporary events, persons and circumstances of the American scene. However it is readable throughout, many of the scientific articles reflecting the pains that have been taken to make the work accessible to the nontechnical reader. For a small encyclopedia, *Everyman's* has no peer.

Nature's Ways, by Roy Chapman Andrews. Crown Publishers, Inc. ($3.75). An illustrated collection of odd facts about plants and animals, intended to convey the impression that Nature is marvelous but succeeding only in establishing the fact that man is vulgar. Many of the curiosities gathered by Dr. Andrews are banal; the text is often condescending and the titles contrived for each brief essay are cute beyond belief (*e.g., The Flower's Revenge, The Gnu's Front Bumper, Huff and Puff, The Kangaroo Needs No Baby Sitters, Scarecrows Don't Scare Crows* and so on).

Science: Its Method and Philosophy, by G. Burniston Brown. W. W. Norton & Company, Inc. ($3.50). A series of essays by a British physicist dealing with a variety of topics intended to illuminate the nature of scientific thought. Brown writes about Newton, logic, animal psychology, Bacon, Aristotle, semantics, religion, non-Euclidean geometry, Samuel Pepys, orangutans, penicillin, cockroaches, Zeus, the bubonic plague and other things—all very clearly and gracefully. An effort is made to connect these various excursions into a single journey, but Brown's book comes off best as an interesting companion to other more unified and balanced works on the subject.

Palace of Industry, 1851, by C. R. Fay. Cambridge University Press ($3.00). An account of the famous Crystal Palace Exhibition, who conceived and planned it, how it came about, what it contained, how contemporaries saw it, and its effects on British commerce, industry and education. Charles Dickens, who found the exhibit somewhat tiresome, observed that at least, as a result of the immense influx of visitors from abroad, "the editors of foreign newspapers will no longer declare that we live on raw beef steaks, and occasionally eat the winners of our Derbies; that every nobleman takes his 'bouledogue' to court with him; that we are in the daily habit of selling our wives in Smithfield market; and that during the month of November three-fourths of the population of London commit suicide." Fay records the financial success of the great exhibition and attempts to show, not always convincingly, its important long-range benefits. The overemphasis is, however, a minor consideration; this is an entertaining book, filled with amusing anecdotes. It is also beautifully designed and printed.

Science: Sense and Nonsense, by John F. Synge. W. W. Norton & Company, Inc. ($2.75). The author, who is professor of theoretical physics at the Dublin Institute for Advanced Studies, discusses the relation between mathematics and experimental science, inconsistencies and paradoxes of scientific thought, certain problems of philosophy and the future direction of intellectual effort. This is a sharp, witty, controversial essay in which Professor Synge, busy sweeping away rubbish, is occasionally himself swept away by his amusing fancies. His habit of teasing the reader by leaving carefully propounded, crucial questions unanswered also gets to be something of a nuisance.

Bibliography in an Age of Science, by Louis N. Ridenour, Ralph R. Shaw and Albert G. Hill. The University of Illinois Press ($2.50). The second annual Windsor Lectures, dealing with an increasingly serious dilemma, namely that books and periodicals are multiplying faster than libraries can find room for them, and that the information they contain threatens to engulf rather than to assist the persons for whom it is intended. The three speakers—two physicists and a professional librarian—review recent advances and propose new methods for bringing the monster under control: ingenious storage devices, electronic information sorters, selectors, computers, digesters and coders. It becomes apparent from these pages not only that the problem is far from solution, but that in tackling it, it will be necessary fundamentally to reevaluate the task of gathering information, of classification and cross reference, and perhaps, indeed, of communication and learning itself. An unusually interesting discussion; also an example of distinguished bookmaking.

For Engineers...

YOUR CAREER OPPORTUNITY of A LIFETIME... at RCA-NOW!

If you are facing a big question: "What is the best move I can make to further my career?"—we believe you will find the answer on this page.

Today, as never before, RCA is engaged in far-reaching electronic developments that have created a need for career men of talent. This means you have the chance of a lifetime to make a permanent connection with RCA in a position offering you the opportunity of a successful career in the field of your choice. Here is what RCA offers.

Wide Choice of Projects

Unusual opportunities await qualified ELECTRONIC, ELECTRICAL and MECHANICAL ENGINEERS . . . PHYSICISTS...METALLURGISTS...CHEMICAL and CERAMIC ENGINEERS — in research, development, design and application, also in technical sales. Positions open provide qualified engineers the opportunity to choose the area of activity they like best.

POSITIONS OPEN IN THE FOLLOWING FIELDS:

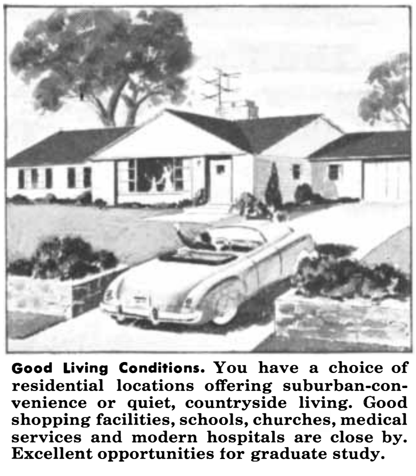
- TELEVISION DEVELOPMENT—
  - Receivers, Transmitters and Studio Equipment
- ELECTRON TUBE DEVELOPMENT—
  - Receiving, Transmitting, Cathode-Ray, Phototubes and Magnetrons
- TRANSFORMER and COIL DESIGN
- COMMUNICATIONS—
  - Microwave, Mobile, Aviation, Specialized Military Systems
- RADAR—
  - Circuitry, Antenna Design, Computer, Servo-Systems, Information Display Systems
- INDUSTRIAL ELECTRONICS—
  - Precision Instruments, Digital Circuitry, Magnetic Recording, Industrial Television, Color Measurements
- NAVIGATIONAL AIDS
- TECHNICAL SALES
- ELECTRONIC EQUIPMENT FIELD SERVICE

If you qualify for any of the positions listed above, write us for a personal interview—include a complete resumé of your education and experience. Write to:

Mr. Robert E. McQuiston, Specialized Employment Division,
Dept. 111V, Radio Corporation of America,
30 Rockefeller Plaza, New York 20, N. Y.

Professional Status. RCA engineers enjoy the highest professional recognition among their colleagues. You work in close collaboration with scientists and engineers who are distinguished in the industry. You receive recognition for your accomplishments.

Laboratory Facilities. At RCA, unexcelled laboratory resources and advanced technical apparatus are available. You have unlimited opportunities for the complete expression of your talents in the fields of electronics.



Good Living Conditions. You have a choice of residential locations offering suburban-convenience or quiet, countryside living. Good shopping facilities, schools, churches, medical services and modern hospitals are close by. Excellent opportunities for graduate study.

Position Security. These are not temporary positions. Activities are focused not only on the long-range national defense program, but also on a diversified line of products for commercial use. You and your family are protected by Company-paid hospital, surgical, accident, sickness, and life insurance. A modern retirement program helps provide for your future.

Rapid Advancement. Opportunities at RCA are exceptional, for you to move ahead in the career of your choice. You can advance to high-level and supervisory positions which are filled from RCA's engineering staff. Salaries, determined on the experience and ability of individual applicants, are reviewed at regular intervals for increases on a merit basis.

RADIO CORPORATION of AMERICA

THE AMATEUR ASTRONOMER

Conducted by Albert G. Ingalls

THOUSANDS of people are using binoculars with faulty adjustments which they would quickly discover if they were equipped to test them even roughly. The two telescopes that constitute a binocular must be identical and almost perfectly parallel or they will cause severe eyestrain. The formulas in Donald H. Jacobs' *Fundamentals of Optical Engineering* give a tolerance for non-parallelism in 7× binoculars of only 3.75 minutes of arc for convergence, and 1.3 minutes for divergence horizontally and vertically.

Binoculars that leave the factory fully adjusted or collimated often lose their parallelism because of wear in the hinge mechanism, or from the ministrations of the grown-up small boy who feels he is a pretty good mechanic but forgets, as he takes the binocular to pieces, that the factory assembler enjoyed the help of jigs and instrumental aids.

The approximations that result from home assembly are usually tolerated only because most people use a binocular for just a few moments at a time. It would be possible to rate binoculars in terms of minutes. A badly collimated binocular will cause a headache in one minute or less. A "five minute" binocular is one that allows its user 299 seconds B.H. (before headache). A perfectly collimated binocular even if used all day should cause no more headache than your spectacles.

Felix Luck of 651 Lincoln Ave., Orange, N. J., has devised a practical collimator that should improve the performance of many binoculars. It is not perfect. Ideal equipment would be much too troublesome to build for less than a dozen jobs of collimation. The practical advantage of Luck's compromise, which costs less than a dollar for materials, is that it is so easy to build that it will actually be built and used. Though it is made of wood with no more complex tools than a saw, hammer and square, it must be built precisely, with meticulous attention to its rigid geometrical control. Luck describes it thus:

"In my frequent travels around the nation I have been impressed with the large number of tyros who are building or have built binoculars from war-surplus materials and who acutely need a simple means of obtaining a reasonably close collimation. An exact collimation is a laboratory job. The method to be described, if followed with reasonable care, will result in a binocular that can be used for long periods without the eyestrain and discomfort associated with a poorly collimated instrument or even with one that is collimated well enough to appear good for the first several minutes of use. Most of the commonly used methods are simply the 'look, blink, look' kind without accessory apparatus. Unless the user enjoys a natural feel for this work, it often results in a poorly collimated glass, many cuss words and much loss of time. The quick method to be described should give more accurate results than any of these expedients, and give them in minutes instead of days.

"The present article does not deal with the assembly of a binocular. It is assumed that the halves are alike optically and mechanically and that the axes of the tubes and the hinge are parallel. A fairly good test for mechanical parallelism is to stand the binocular on end on a surface plate or plate glass at both the widest and the smallest eyepiece separation. In each position both of the objective tubes should rest squarely on the plate without rocking. This test assumes that the ends of the tubes are square with the sides and axes. The halves are almost sure to be alike if matched optics and metal parts have been purchased and carefully assembled, but great care should be taken to be sure of their sameness if random optics and parts are used. No amount of careful collimation will prevent eyestrain if, for example, the sizes of the images produced by the halves are unequal.

"The first requirement is a source of parallel light rays. The simplest and cheapest is the sun. Next is a projection lens, a simple plano-convex or double-convex of 4½-inch diameter and 10- or 12-inch focal length: the lens from a typical large reading glass. It must be wide enough to cover the eyepieces of the binoculars at their greatest separation. If it is wider, the unused width should be masked off to cut down on heat, since the lens also acts as a burning glass. The focal length will determine the diameter of the image, but this is not critical. Nor will chips on the lens make trouble.

"This lens, covered with a mask with curved slots corresponding in their lower halves to different positions of the binocular hinge, and left open in their upper halves to permit the passage of the solar rays, is mounted in a circular recess in a board. The binocular is attached between this lens and the sun. When the binocular is correctly collimated at all positions of the hinge, the two solar images made by it will be refracted by the lens and will coincide as a single image on the screen at the rear, while the smaller image made by rays passing directly through the upper halves of the openings in the mask instead of through the binoculars and the lens will be concentric with the image from the binocular. The openings in the mask are curved, as shown in the illustration [*see next page*], and concentric with the center of the lens to permit testing the binocular with its hinge at different angles between the bottom of the openings and the horizontal. Their upper parts that admit the sun's rays to the lens are equally curved to insure that the rays will all pass through the *same zone* of the lens and all be subject to equal spherical and chromatic aberrations, an important consideration when using a single lens for projection. This symmetry automatically eliminates the aberrations from consideration.

"It makes no difference whether the light passes through the whole lens, part of it, or several areas simultaneously; a complete image and only one image will be formed, provided the target is placed at the principal focus of the lens. Theoretically, spherical and chromatic aberrations will create a number of overlapping images, but in practice this effect is negligible.

"When the eyepieces of the binocular are properly focused, the parallel rays of light entering the objective lenses form an image at the focus and pass out through the eye lenses again parallel. But if the optical axes of the binocular halves are not parallel, the two images of the sun formed by them will not coincide, because the bundles of rays leaving the eyepieces will not be parallel with one another and after passing through the large lens will form images at different points on the target. The trick is therefore to bring these two images into coincidence. This may be accomplished in most binoculars by adjusting the eccentric rings around the objective lenses.

"Professional binocular servicemen position the hinge so that its axis coincides with that of the large lens, then bring the halves of the binocular into coincidence. This is done so that collimation will be effected for all interpupillary settings of the hinge. With our simple collimator this would be a complicated process. Therefore an ap-

6 POWER BINOCULAR
$16.95
Also 7 Power
$21.95

COATED! Pocket size—weigh only 4 oz. and 7 oz. respectively! Field of 370 ft. at 1000 yds.! Precision constructed PRISM binoculars. Not Field Glasses. Made of lightweight, durable black and chrome metal. Achromatic lens. *Carry the United seal of quality.*

16x50
$69.50

Easy to Hold, Easy to Focus

The ultimate in fine binoculars. Tremendous power (Full 16 power). *Featherweight* (weigh only 24 ounces!). Precision made in every detail. COATED providing sharper, brighter images. Individually focussing. Objective lens is 50 mm (2 inches) across!

SIX TELESCOPES IN ONE!

15 to 40 POWER

$30.75 COATED

American made Wollensack telescope. Instant focussing at 15x, at 20x, 30x and 40x, etc. Turn power tube to click—no guesswork. Telescope measures 9″ closed. 27″ when extended. Weighs only 18 oz.! Has rustproof chrome tubes. large 40 mm objective lens. All 12 optic surfaces are COATED. See .22 bullet holes clearly at 300 feet. Use also for astronomical observation. $30.75 price *includes* tax and fine leather case.

UNCONDITIONALLY GUARANTEED

Try at our risk and expense. If not completely satisfied return for an immediate unquestioned refund of your money. Prices include genuine leather carrying case and straps for each pair of binoculars. Cash orders sent postpaid. C.O.D.'s require $2.00 deposit. Add federal tax.

UNITED BINOCULAR CO.
9043 S. Western Ave. Dept. ARF-1627 Chicago 20, Ill.
Display Sales Rooms Open 9:00-3:30 Mon. thru Fri.

WAR SURPLUS BARGAIN

OPTICS

ACHROMATIC TELESCOPE OBJECTIVES—Perfect Magnesium Fluoride Coated and cemented Gov't Surplus lenses made of finest Crown and Flint optical glass. They are fully corrected and have tremendous resolving power and can be readily used with 1/4″ F.L. eyepieces. Guaranteed well suited for Astronomical Telescopes, Spotting Scopes, etc. Original Gov't cost approximately $100.00 each.

Diameter	Focal Length	Each
54m/m (2⅛″)	300m/m (11.811″)	$12.50
54m/m (2⅛″)	330m/m (13″)	$12.50
54m/m (2⅛″)	390m/m (15.356″)	$ 9.75
54m/m (2⅛″)	600m/m (23½″)	$12.50
78m/m (3 1/16″)	381m/m (15″)	$21.00
81m/m (3 3/16″)	622m/m (21½″)	$22.50
83m/m (3¼″)	660m/m (26″)	$28.00
83m/m (3¼″)	711m/m (28″)	$28.00
83m/m (3¼″)	876m/m (34½″)	$28.00
83m/m (3¼″)	1016m/m (40″)	$30.00

We can supply ALUMINUM TUBING for the above lenses.

SYMMETRICAL EYEPIECE LENS SET—These sets consist of two Magnesium-Fluoride coated and cemented achromats, exact Gov't spacing diagram. Gives wide flat field.

½″ E.F.L. (20X) Lens Set 13m/m Dia..... $4.50
¾″ E.F.L. (13X) Lens Set 18m/m Dia........3.50

MOUNTED EYEPIECE has 2 perfect lenses 29mm in dia. Designed in order to give good eye relief. Cell fits 1¼″ tube. 1¼″ E.F.L. (8X)........... $4.50

MOUNTED EYEPIECE has 2 perfect achromats, 27mm dia. Cell fits 1¼″ tube. 1 7/16″ E.F.L. (7X) $4.00

BINOCULARS, beautiful imported binoculars, precision made, at a low low price within the reach of every man's pocketbook. Complete with carrying case and straps.

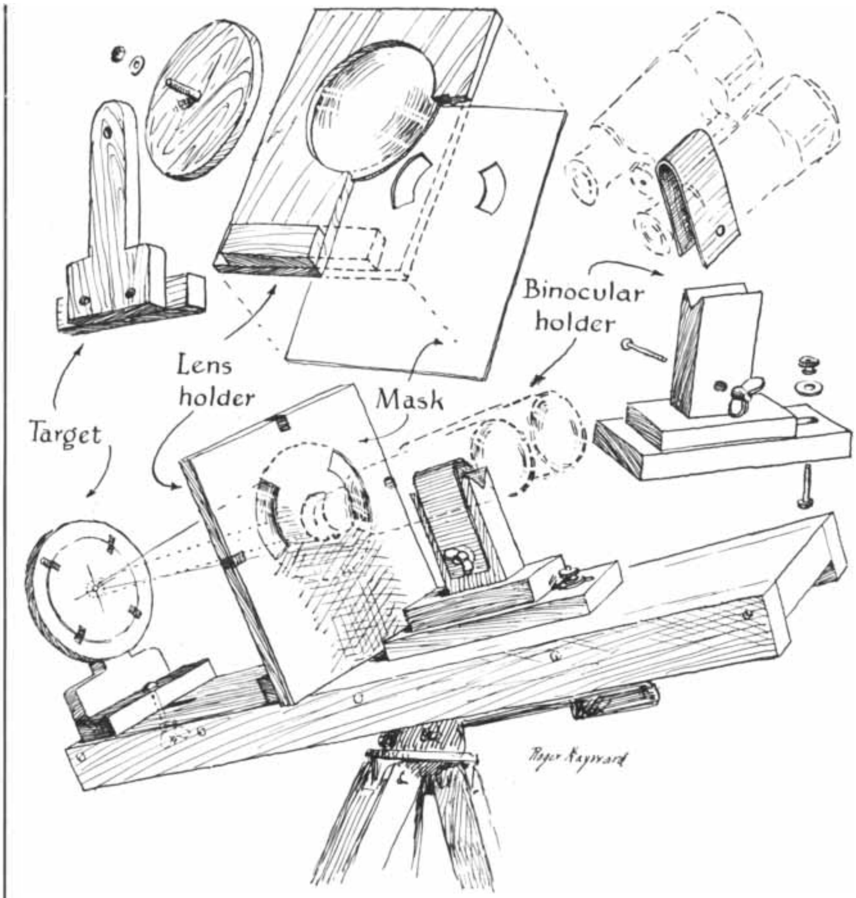
8x25		$23.30*	Postpaid
8x30		29.50*	Postpaid
7x50		33.75*	Postpaid
7x50	Coated	39.75*	Postpaid
10x50		50.00*	Postpaid
10x50	Coated	60.00*	Postpaid
7x35		60.00*	Postpaid
7x35	Coated	65.00*	Postpaid
16x50	Coated	60.00*	Postpaid

*Plus 20% Excise Tax

Free Catalogue
"MILLIONS" of Lenses, etc.

We pay the POSTAGE—C.O.D.'s you pay postage—Satisfaction guaranteed or money refunded if returned within 10 days.

A. JAEGERS 93-08A 95th Ave.
OZONE PARK 16, N. Y.



Simple apparatus for removing eyestrain from binoculars

proximation that has produced satisfactory results is recommended.

"The target should be set permanently at the principal focus of the large lens in sunlight and must be adjusted rigidly square with the baseboard. The lens board too should square with the baseboard in both directions and should hold the lens in a similar position on the side toward the target. The support for the binocular should hold its hinge rigidly perpendicular to the face of the lens in all planes, yet permit changing the interpupillary setting without disturbing the position of the hinge. I have found empirically that an interpupillary setting of 63 millimeters, a mean distance for men and women, will serve for settings three or four millimeters on either side. If that setting is used the binoculars will not be too far wrong for most other settings, thus avoiding the necessity of moving the hinge. Yet the less simple approach of collimation at a number of hinge settings is preferable if only as a check.

"At the center of gravity of my gadget I put a nut in the baseboard to fit a standard camera tripod screw. Thus, by using a pan head on the tripod I have an equatorial mounting which facilitates pointing the gadget at the sun as the sun moves. This really helps.

"To line up the gadget, move the target until the diameter of the solar image is single and a minimum. It is well to cover either hole in the mask separately, examining the image with a low-power magnifier to note whether it is circular and whether it has a flare on one side caused by lack of squareness in the position of the target or the lens. Clamp the binocular hinge to its support, point the gadget at the sun and observe the images. There will probably be three, one small image from the lens and two larger ones from the binocular. If there are but two and these are concentric, the binocular is collimated for the one-hinge setting; such luck is uncommon.

"A short cut to collimation, even though illogical in theory, is to move the binocular so that the magnified image nearest the center of the target is concentric with the small image from the lens, which must be at the center of the target. Clamp the binocular and cover first one half, then the other, to be sure which half is forming which image, since they may be crossed. Then move the eccentric until all three images are concentric and those from the binoculars coincide and are at the center of the target.

"This provides collimation for a single setting of the hinge, but it should be repeated at other settings. If the lack of coincidence at other settings is not greater than 1/25 the diameter of the magnified image (for binoculars of

© 1951 SCIENTIFIC AMERICAN, INC

eight power or less) all is well. If, however, more than a slight movement of the binocular hinge out of square is required, do not move the binocular hinge but, when the small image is exactly at the center of the target, adjust the eccentric rings of both halves to bring the large images concentric with the small and into coincidence with each other.

"It will still be necessary to try other interpupillary settings, as there is no certainty that the hinge is truly in the line of sight even though care was used in setting up the gadget. If the lack of coincidence is greater than 1/25 the diameter of one of the large images, the hinge alignment is too far out of the line of sight. (It was assumed only that the hinge axis is parallel with the axis of the tube, a part of the construction of the binocular.)

"Be sure that the small image is centered on the target before moving the eccentric rings. The center of the target should be marked with a cross. Each time after bringing the large image to its proper place in relation to the small image or to the other large image, repoint the gadget to the sun. The sun's motion will probably not be as large as that due to moving the rings and is of little importance. The large image moves faster than the small one when the gadget is moved and when the sun moves, in proportion to the magnification of the binocular. Disregard the color fringes on the images. If the images from the halves are not equal in diameter the halves of the binocular are not alike."

Luck's gadget would have been appreciated some years ago by the conductor of this department, who is still cross-eyed in one eye and wall-eyed in the other from attempting the method of looking through the binoculars while collimating. On that occasion the parts were finally bundled off to William Waldeyer of 2701C McAllister St., San Francisco, Calif., an amateur telescope maker and professional binocular serviceman, and came back so well assembled and collimated that no eyestrain resulted from prolonged observation at a bathing beach.

During World War II Dr. G. Dallas Hanna, a paleontologist on the staff of the California Academy of Sciences who has an interest in fine mechanism, headed a group of amateurs making roof prisms as a part of this magazine's amateur roof-prism program. He was soon discovered by the U. S. Navy, which began bringing him damaged fire-control instruments, and later binoculars. Hanna directed 50 employees reconditioning binoculars in the museum of the Academy, and Waldeyer was the foreman of this force, which reconditioned 6,000 binoculars. Hanna, who became an expert, says that Luck's method of collimating is "perfectly sound and practical."

SAVE 95%
ON PERIODICAL STORAGE SPACE

"SCIENTIFIC AMERICAN and over 750 other leading periodicals are now available on microfilm——cost about equal to library binding. Microfilms of issues from May 1948 (first issue of *new* SCIENTIFIC AMERICAN) may be secured."

Addressing inquiries to us on your organization's letterhead will help us be of better service to you. Write for details to Department SA.

UNIVERSITY MICROFILMS
ANN ARBOR, MICHIGAN

U M

Amateur Telescope Making

- 500 pages, 316 illustrations $5.00 postpaid, domestic; $5.35 foreign

Amateur Telescope Making Advanced

- 650 pages, 361 illustrations $6.00 postpaid, domestic; $6.35 foreign

Send a postal card for detailed information on these two books

SCIENTIFIC AMERICAN
24 West 40th Street, N. Y. 18

WAR SURPLUS BARGAINS
35 POWER
ERECTING MICROSCOPE

Amazing Clarity
"All-Position" Universal Mount
Greater Versatility

3″ of Working Space from Objective to Platform . . .

A TRULY FINE OPTICAL INSTRUMENT Worth $75.00 But Our Price ONLY $29.50 COMPLETE

A remarkable Instrument! Exceptional Value! Prism Erectors give you an erect image—exactly as your eye sees it, not upside-down as in an ordinary Microscope. Ramsden Eyepiece permits fine precision focusing. 3-Element color corrected objective—1″ diameter. Microscope body is of brass with black crackle finish. Working distance from objective to object is 3″, which permits any work, dissection, tooling, etc., to be carried on "under power" while looking through Microscope. The instrument is 6½″ long with base 7″ x 9″. Only because we were able to utilize some war surplus parts are we able to offer such a fine Optical Instrument—easily worth $75.00—at this special low price.
Stock #970-S ....$29.50 Postpaid

SIMPLE LENS KITS!—THE LENS CRAFTER'S DELIGHT! Fun for adults! Fun for children! Kits include plainly written, illustrated booklet showing how you can build lots of optical items. Use these lenses in photography for copying, **ULTRA CLOSE-UP SHOTS,** Microphotography, for "Dummy Camera". Kodachrome Viewer, Detachable Reflex View Finder for 35 mm. cameras, Stereoscopic Viewer, ground glass and enlarging focusing aids. And for dozens of other uses in experimental optics, building **TELESCOPES**, low power Microscopes, etc.
Stock #2-S—10 lenses ....$1.00 Postpaid
Stock #5-S—45 lenses ....$5.00 Postpaid
Stock #10-S—80 lenses ..$10.00 Postpaid

SLIDE PROJECTOR SETS—Consist of all unmounted lenses you need to make the following size projectors:
Stock #4029-S—35 mm ....**$2.85 Postpaid**
Stock #4038-S ....2¼″ x 2¼″.... ....**$3.35 Postpaid**
Stock #4039-S ....2½″ x 3½″.............**$3.35 Postpaid**

NON-ABSORBING BEAM-SPLITTING MIRROR—Latest development! Optically flat to ¼ wave length. Size: 1 15/16″ x 2 15/16″—⅜″ thick. Reflects approximately 50% and transmits approximately 50%. No light is absorbed. Has a three-layered film which accomplishes non-absorption.
Stock #567-S.... ....$5.00 Postpaid

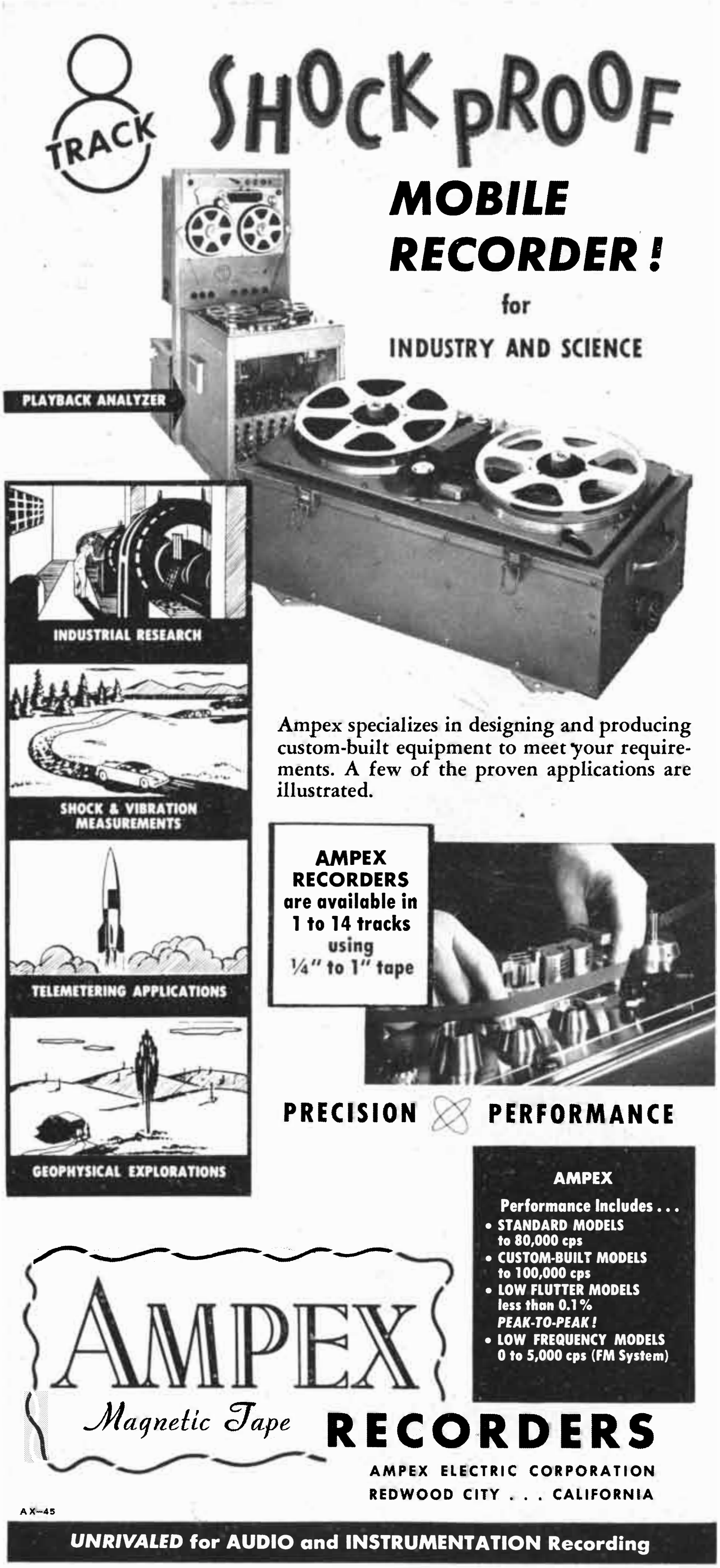
MOUNTED ANASTIGMAT LENS—Free booklet with your order: "How to Make Your Own Enlarger." Speed f/7.7, focal length approx. 127 mms. Suitable for pictures, negatives, positives up to 3½″ x 4¼″.
Stock #8004-S.......................... ....$7.50 Postpaid

Order by Stock No.—Send Check or M.O.
Satisfaction Guaranteed!

We have Literally Millions of WAR SURPLUS LENSES AND PRISMS FOR SALE AT BARGAIN PRICES
Write for Catalog "S"—SENT FREE!

EDMUND SCIENTIFIC CORP.
(Formerly Edmund Salvage Co.)
BARRINGTON, NEW JERSEY

© 1951 SCIENTIFIC AMERICAN, INC



BIBLIOGRAPHY

Readers interested in further reading on the subjects covered by articles in this issue may find the lists below helpful. The lists are not intended as bibliographies of source material for the articles. The references selected will provide supplementary information.

INPUT-OUTPUT ECONOMICS

The Structure of American Economy 1919-1939. Wassily W. Leontief. Oxford University Press, 1951.

THE STATE OF GENETICS

The Genes of Men and Molds. George W. Beadle in *Scientific American,* Vol. 179, No. 3; September, 1948.

The Genetic Basis of Evolution. Theodosius Dobzhansky in *Scientific American,* Vol. 182, No. 1; January, 1950.

SYNTHETIC DETERGENTS

Surface Active Agents, Their Chemistry and Technology. Anthony M. Schwartz and James W. Perry. Interscience Publishers, Inc., 1949.

The Fundamentals of Detergency. William W. Niven, Jr. Reinhold Publishing Corp., 1950.

THE NEUTRON

Why Smash Atoms? Arthur K. Solomon. Harvard University Press, 1946.

The "Particles" of Modern Physics. James Docking Stranathan. The Blakiston Company, 1945.

RADIATION FROM A REACTOR

Cerenkov Radiation. George B. Collins and Victor G. Reiling in *The Physical Review,* Vol. 54, No. 7, pages 499-503; October 1, 1938.

ERNEST STARLING

The Croonian Lectures on the Chemical Correlation of the Functions of the Body. Ernest Henry Starling in *The Lancet,* Vol. 2, pages 339-341; August 5, 1905.

The Linacre Lecture on the Law of the Heart. Ernest Henry Starling. Longmans, Green & Company, Inc., 1915.

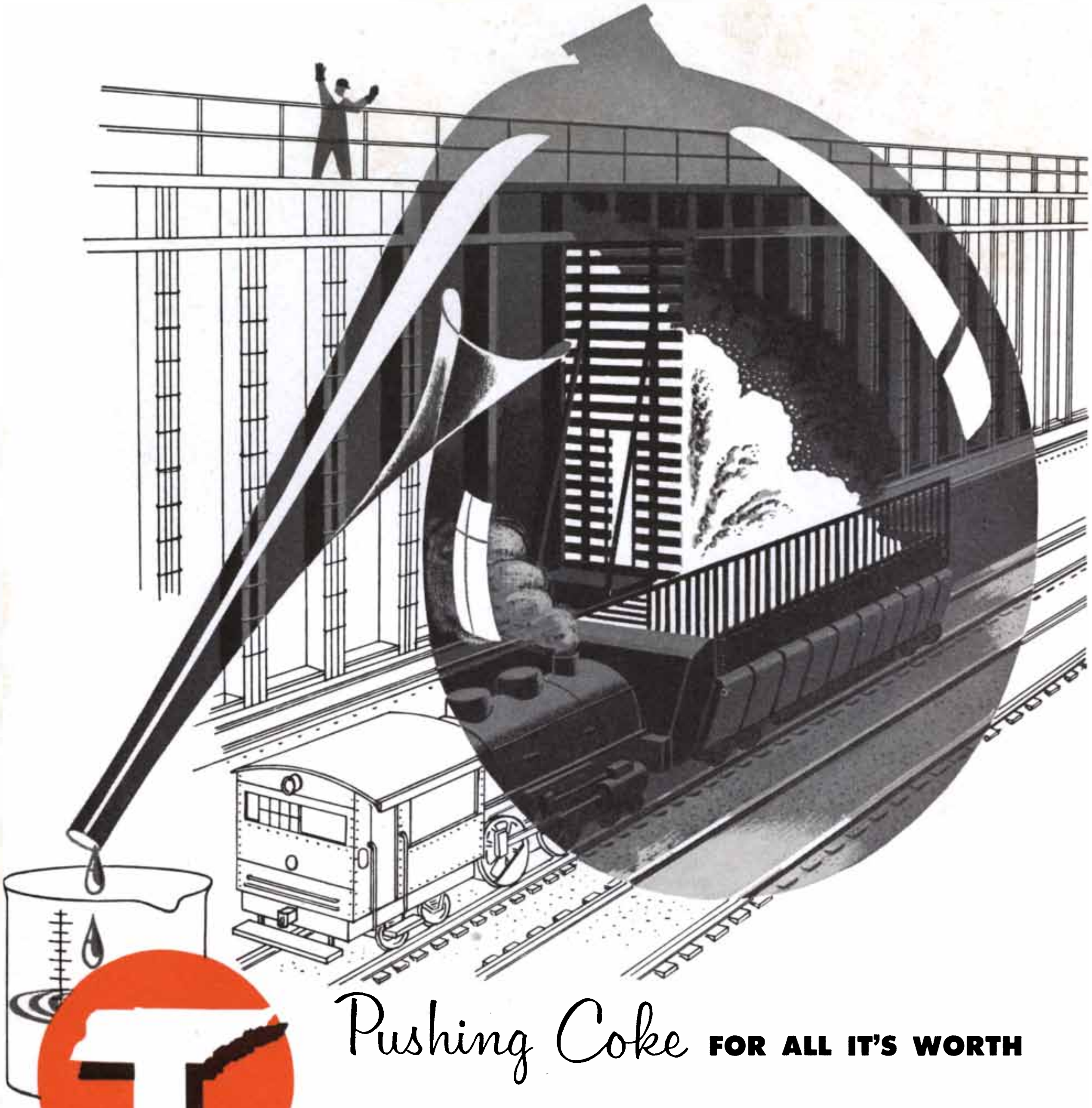
HALLOWEEN

Halloween Through Twenty Centuries. Ralph and Adelin Linton. Henry Schuman, Inc., 1950.

LIFE IN THE DEPTHS OF A POND

Life in Lakes and Rivers. T. T. Macan and E. B. Worthington. New Naturalist Library, William Collins Sons & Co., Ltd., 1951.

The Trophic-Dynamic Aspect of Ecology. R. L. Lindeman in *Ecology,* Vol. 23, No. 4, pages 399-418; October, 1942.



Pushing Coke FOR ALL IT'S WORTH

"Pushing" coke out of the ovens is the final stage of making coke from our own coal.

The vapors from this coking operation yield tar, naphthalene, fuel gas and light oils. From the light oil we produce benzene, toluene and xylene — the starting point for Tennessee's production of . . . . benzene hexachloride (BHC) . . . . benzoic acid . . . . benzyl alcohol . . . . muriatic acid . . . . sodium benzoate . . . . benzaldehyde.

For coke or aromatic and agricultural chemicals, you can rely on Tennessee's integrated facilities and control of processing from raw materials to finished products. Tennessee Products & Chemical Corporation . . . . an industry serving all industry.

TENNESSEE
PRODUCTS & CHEMICAL
Corporation
NASHVILLE, TENNESSEE

PRODUCERS OF: FUELS • METALLURGICAL PRODUCTS • TENSULATE BUILDING PRODUCTS • AROMATIC CHEMICALS • WOOD CHEMICALS • AGRICULTURAL CHEMICALS

Photo by Evancy

Help Wanted—Opportunity

Few among the thousands of young women in search of "first jobs" or more satisfactory employment will find a career in which their help is more truly *wanted* or the opportunities more *real* than in the nursing profession.

The student nurse not only receives the finest of training—she also has the deep satisfaction of knowing that she will be serving humanity, winning a place of honor in people's hearts and helping to ease suffering and replace sickness with health wherever she goes.

Today, many opportunities are open for graduate nurses . . . in hospitals, public health, schools, industry, airlines, private duty, research, teaching and other fields . . . all leading to rewarding careers of service. Further information is available from the Director of Nurses at your local hospital.

This advertisement is sponsored by Davis & Geck, Inc., a unit of American Cyanamid Company. D & G's service in the development and production of surgical sutures is well known to surgeons, physicians and nurses throughout the world.

AMERICAN *Cyanamid* COMPANY

30 ROCKEFELLER PLAZA, NEW YORK 20, N. Y.

Sutures for the Surgical Profession—One of the many services performed by Cyanamid