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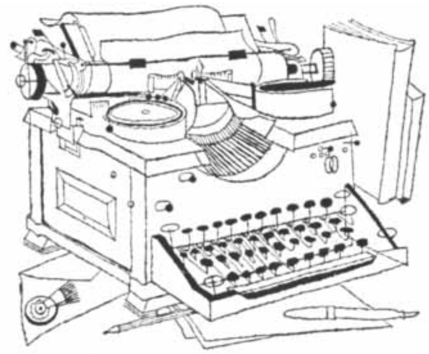

LETTERS

Sirs:

Your September issue, entitled "Automatic Control," was indeed an interesting one. I found it particularly productive to read it in conjunction with your earlier issue entitled "Human Resources of the U. S." These two issues, when read and related to each other, raise some perplexing problems.

How can young people be aided to select those occupations for which they have the aptitudes, capabilities, and, of the utmost importance, the interest and drive to work toward success? What kinds of experiences have proven to be successful in helping people who are preparing for careers in scientific fields? In regard to teachers of science, there are some indications that an educational background which includes some engineering is very valuable. Would science teachers with this kind of background help to guard against a future shortage of competent engineers? It would also seem that this new technology will make it increasingly imperative that everyone not only know how to do a job or a piece of required work, but also be able to see how this work is connected with the work of other people and how it fits into the total operation which includes machines and their controls. The maintenance man will have to understand what it would mean to hit a $50,000 controller with a hammer, "if," as your author says, "the shaft doesn't fit into the hole on the first try." How can people learn to see the job that they do as a vital part of an important whole? These are some of the questions that are raised by these two outstanding issues of *Scientific American*. We have had answers to some of these questions. However, it would seem that some of our old answers no longer fit our times. Can we find new and better answers for the future?

WILLARD JACOBSON

Teachers College
Columbia University
New York, N. Y.

Sirs:

I read with great interest your issue on automatic control; and I agree that this new technological "revolution" has tremendous implications for the social sciences and their applications.

The concept of the closed-loop, self-regulating economic system is very old, dating at least from Adam Smith's *Wealth of Nations.* (Note that Smith's "invisible hand" is of approximately the same age as Watt's governor.) Moreover, the feedback principle (not under that name) has been the basis of theoretical self-regulation.

Twentieth-century economics, especially Keynesian economics, has led to a re-formulation of some of the economic circuits, a rejection of assumed built-in corrective feedback, and a construction of new control systems. It was gratifying to see Professor Tustin's interpretation of the Keynesian system in these terms. However, I feel that the diagram of such a system and its explanatory text are inadequate and misleading, partly because of incompleteness and partly because the true feedback loops of a control system are not shown.

First of all, it will be noted that the system as it stands is "open" in three areas: international transactions, the rate of interest, and employable population. In reality the relation between incomes and expectation of profit is extremely tenuous, most major changes in profit expectations arising from "exogenous" stimuli, such as war, technological innovation, government policy, etc. Such relation as exists is called the "accelerator effect" and constitutes an element of positive instability in the system. For control purposes, therefore,

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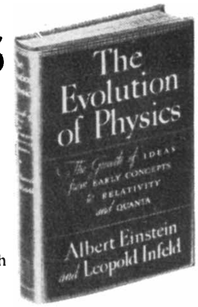

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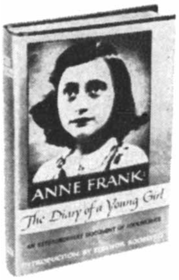

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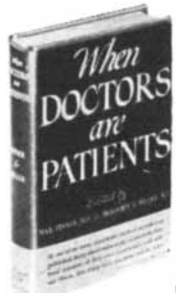

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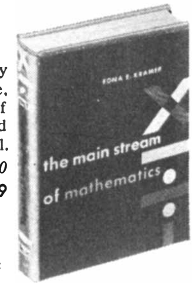

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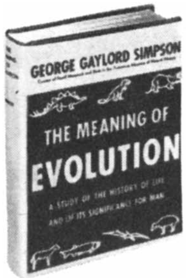

Called by the New York *Times,* "Without doubt the best general work on evolution to appear in our time," this is a vital study of the history of life and of its significance for man.
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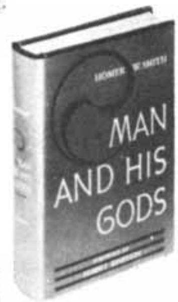

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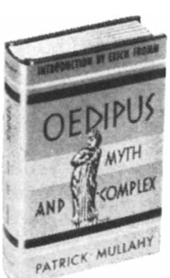

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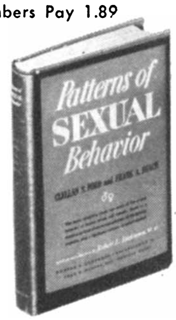

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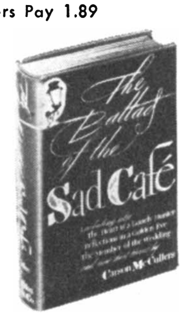

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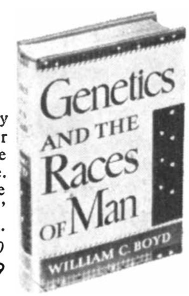

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expectation of profit must be regarded as an "open" area, and the capital goods-income circuit as incomplete.

The control system suggested by Keynesian economics is compensatory action by government. This action may be broken down into monetary policy and fiscal policy, the former carried out by a central bank, the latter by the public treasury. Monetary policy feeds back corrections to the rate of interest. Fiscal policy feeds back corrections to net foreign transactions and domestic investment. Employable population remains as the single independent input, which may be assumed the basic material of the problem of control (for our immediate purposes), corresponding to crude petroleum in the automatic refinery.

Now the central bank emits cash and depresses the rate of interest (non-linear function) as net expectation of profit, decisions to invest, etc., decline and unemployment rises; and it absorbs cash to raise the rate of interest as the opposite conditions obtain. The treasury reduces intake (taxes) and increases output (expenditures) as domestic plus net foreign investment decline, thus to raise consumable incomes (linear function); that is, the treasury reduces surplus or increases deficit, the latter absorbed ideally by "idle" savings or emission of new cash through the banking system. The opposite reaction follows from an increasing total of foreign and domestic private investment.

These, then, are the major control loops in the Keynesian system. It must be pointed out, however, that to represent automatic feedback the above actions would have to rest upon law and firmly established policy, with specific criteria, rather than depend upon political expediency and conflicting personal judgments of bureaucrats, congressmen, and businessmen.

STEPHEN L. McDONALD

Department of Economics
University of Texas
Austin, Texas

ERRATUM

In the subtitle of the article "The Diphtheria Toxin," which appeared in the October issue of this magazine, it was stated that "the substance secreted by the diphtheria bacillus is one of the most potent poisons known: one milligram of it is enough to kill 1,000 tons of guinea pig." Actually one milligram of the toxin will kill only 3½ tons of guinea pig. The larger figure is true of the tetanus and botulinus toxins, as stated in the article.

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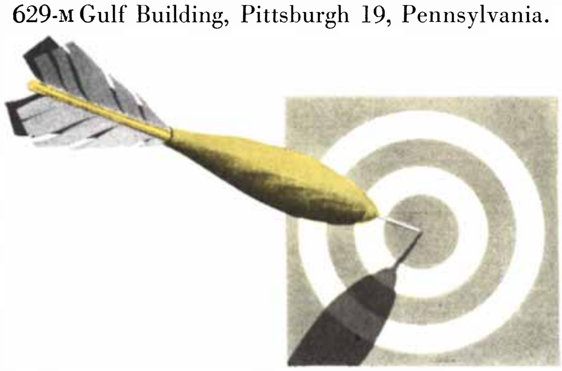

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50 AND 100 YEARS AGO

DECEMBER, 1902. "We have just had news of the smashing of Winton's new track record, made in the world renowned 'Bullet,' by Henry Ford, of Detroit. Mr. Winton, on the Glenville track at Cleveland, September 16 last, made a new track record of a mile in 1:02 1/4, against his previous record of 1:06 2/5, made about a year ago. Mr. Henry Ford, of Detroit, on a gasoline racer built by himself and Tom Cooper of that city, has just succeeded in beating Mr. Winton's time by more than a second, having established a new record December 1 on the Grosse Pointe track, Detroit, of a mile in 1:01 1/5. This brings the much-sought-for speed of 60 miles an hour, or one minute on a track, within slightly over a second of being attained; so the probabilities are that before long the feat will actually be accomplished."

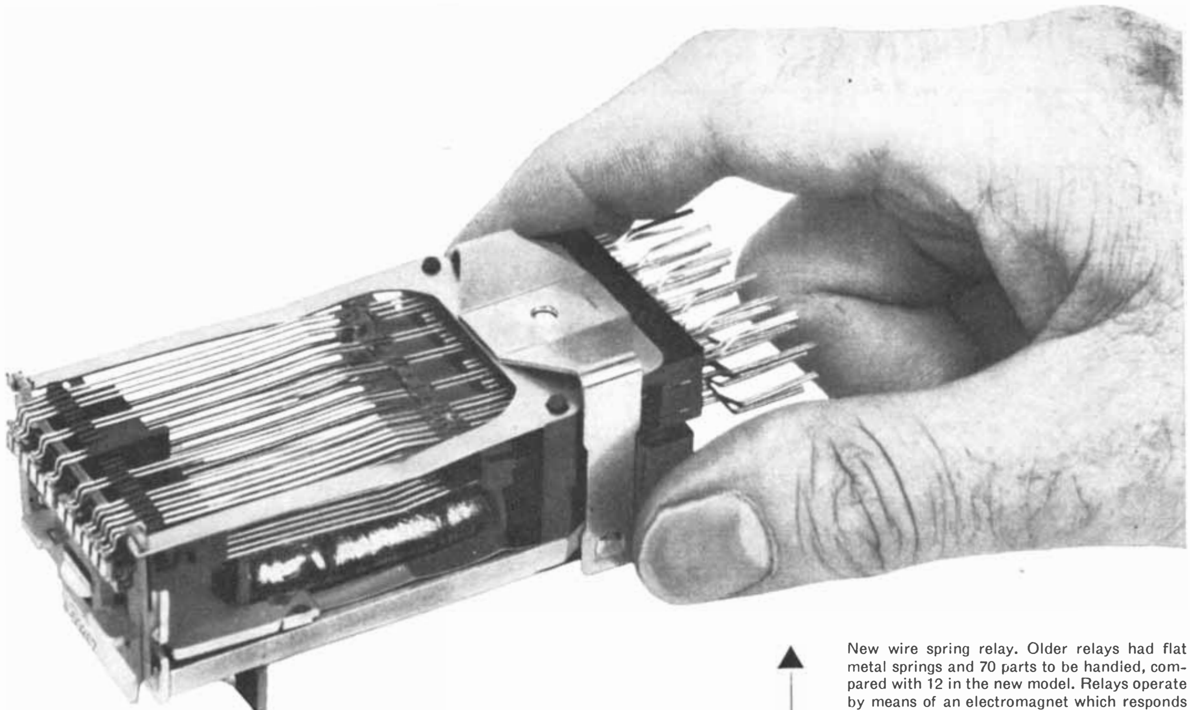
"This year's Nobel prizes have just been announced. The honors in physics were divided by Dr. H. A. Lorentz and Dr. P. Zeeman, both of Holland. The chemical prize was taken by Dr. Emil Fischer, of Berlin. The medical prize was received by Major Ronald Ross, principal of the Liverpool School of Tropical Medicine. The venerable historian Theodor Mommsen received the literary prize. To American readers some of these men may not be well known. Zeeman is the man who discovered that if a beam of light were passed through a magnetic field before being analyzed by a spectroscope, the lines in the spectrum would be doubled. Lorentz worked on kindred subjects—the theory of radiation and the relations of the ether to matter. It is singular that both of these men are Dutchmen, countrymen of the famous van't Hoff, who received the prize in chemistry last year. Fischer is a most versatile scientist. His early work was in the field of coal tar. More recently he has studied the amino and diamino acids, which are products of the decomposition of proteids. To Major Ross is principally due the theory that the mosquito is an active agent in the dissemination of malaria."

"Recognizing the importance of the new transportation and the fact that it will endure, the faculty of Columbia University has added a course in automobile mechanics to the curriculum. Instruction will be given by a competent gas engine expert, and the course will cover gasoline and steam carriages only, the electric vehicle being included in the regular electrical course."

"In Thomas Edison's work there is no guessing, no trusting to luck. Edison knows exactly what he wishes to accomplish, and how his end is to be attained. Absolute certainty of purpose and of method saves him from frittering away his time in useless experimentation. Chance has given perhaps an occasional idea, but it has not lightened his work. A device, whose invention he himself has attributed to accident, is the phonograph. He had taken out a patent on a telegraph repeater, in which a chisel-shaped stylus indented a sheet of paper curled around a cylinder. These indented marks were to be used in retransmitting the recorded message. 'While singing into the mouthpiece of a telephone, the vibrations of the voice sent the fine metal point into my finger,' he tells us. 'That set me to thinking. If I could record the movements of the point and send it over the same surface afterward, I saw no reason why the thing would not talk. I tried the experiment first on a strip of telegraph paper. I shouted "Hello! hello!" into the mouthpiece, ran the paper back over the steel point, and heard a faint "Hello! hello!" in return.' Then he decided to make a talking-machine. The men in the laboratory laughed at him. In the end he proved that he was right. When the first operative phonograph was completed, Edison packed up his instrument and came to the office of SCIENTIFIC AMERICAN. Without ceremony he placed the machine on the Editor's desk and turned the crank. The machine introduced itself. 'Good morning,' it said. 'How do you do? How do you like the phonograph?' And thus it happened that the editors of SCIENTIFIC AMERICAN constituted the first public audience that ever listened to the phonograph."

"A device which does not seem to receive from its makers the attention which it merits is the sprag, the iron rod suspended from the rear axle to hold a car on a grade in case brakes do not operate or are not in use. Too often the sprags fitted to heavy large cars are altogether too slender for the purpose; often they are stout enough, but so short that the car would be certain to ride over them. It is not often that the sprag is needed, but when it is wanted the need is great and immediate, and not only the car, but the lives of its occupants may de-

It splits seconds even faster

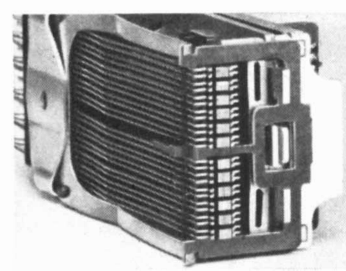


New wire spring relay. Older relays had flat metal springs and 70 parts to be handled, compared with 12 in the new model. Relays operate by means of an electromagnet which responds to high-speed pulses.

IN A split second, relays, which are high-speed switches, set up dial telephone connections. Then they are off to direct the next call. Yet even this speed is too slow for Bell Laboratories scientists in quest of still faster switching.

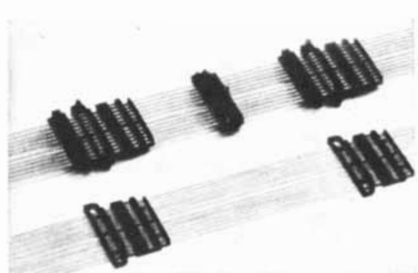
Scientists and engineers devised a new relay – the wire spring relay – and worked out the production problem with Western Electric, manufacturing unit of the Bell System. This is twice as fast, uses less power and costs less to make and maintain.

With speedier relays, switching can be done with less equipment . . . and calls go through faster. The wire spring relay is a practical example of how Bell Telephone Laboratories and Western Electric pool their skills to improve telephone service while keeping its cost down.



New relays must be able to operate one billion times—equal to once-a-second for 30 years. Employing a sound recorder as a precision vibrator, Bell scientists learned to evaluate the effect of sideways motion on relay life. Such rubbing motion is limited to one-thousandth of an inch in the new relays.

Dynamic Fluxmeter, developed by Bell Laboratories, indicates flux build-up in intervals of 25 millionths of a second. Precise information like this was essential to higher speed operation.



Relay springs as they come from Western Electric molding machine, before being cut apart for use. Molding technique saves time and money . . . makes possible the maintenance of precise adjustment.

Bell Telephone Laboratories

IMPROVING TELEPHONE SERVICE FOR AMERICA PROVIDES CAREERS FOR CREATIVE MEN IN SCIENTIFIC AND TECHNICAL FIELDS pend upon the apparently insignificant device."

"It is said that Professor Michael Pupin has sold the European patent rights of his invention for the transmission of telephone messages over long cables to the firm of Siemens and Halske of Berlin. The report made to the firm by its engineer states: 'The experimental tests demonstrate that the insertion of inductance coils into long-distance telephonic conductors, in accordance with Pupin's invention, enables us to obtain in practice the enormous effects required, and that long-distance telephony actually enters into a new area of development. The problem of transatlantic telephony has become through this invention a possibility, even if the technical difficulties of laying a submarine cable in great submarine depths might be considered as exceptionally serious.' "

DECEMBER, 1852. "Dr. Burnett, of Boston, has written an able article on the effect of climate on consumption to the *Boston Medical and Surgical Journal.* From statistics and information which Dr. Burnett has been collecting, he has come to the conclusion that consumptive invalids, to be permanently benefited by a change of climate must go South and make their home there. The climate of Greenville, in South Carolina, and some parts of Georgia is exceedingly favorable to those laboring under this disease; in summer the temperature rarely exceeds 90 degrees, and is free from sudden changes."

"Sir William Herschel has suggested the hypothesis that all matter was originally in a nebulous state, and that, while condensing into solid bodies, it developed great heat. Thus our earth was first a fiery ball, and the surface on which we now live is a mere crust, the rest not being cooled yet. This hot interior, when reached by water, causes an explosion like a steam boiler. The author of *The World Without* states how easy it is to account for volcanoes by this theory, saying—'according to the fiery nebulous theory, the earth, at a depth of sixty-five miles, is 7,000 degrees temperature, and if water percolates through fissures of the earth, we have a sufficient explanation of earthquakes and volcanoes.' "

"The introduction of sewing machines for stitching shoes is becoming quite common. One establishment in Abington, Mass., uses no less than six. It is said that an operator, with the machine, will stitch in a day more than ten times the amount usually accomplished by a 'stitcher,' and that the cost is very materially reduced. Who, a few years ago, would have thought that our coats and shoes would ever have been stitched by iron fingers?"

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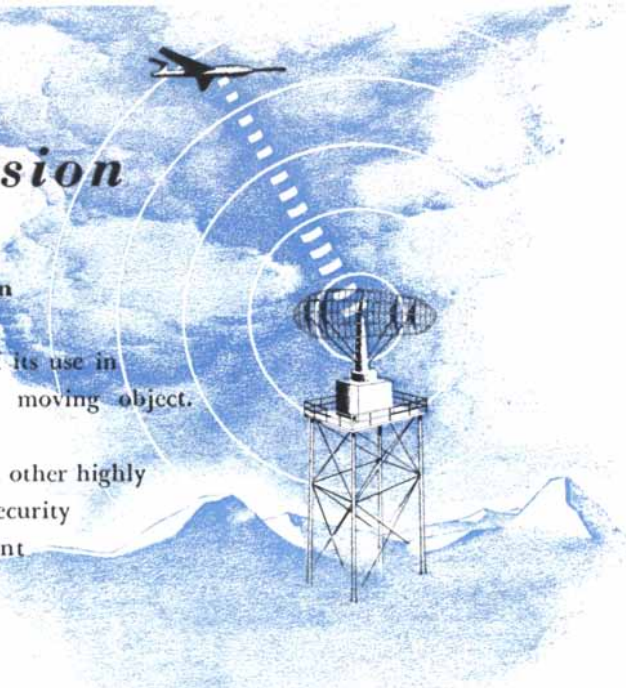

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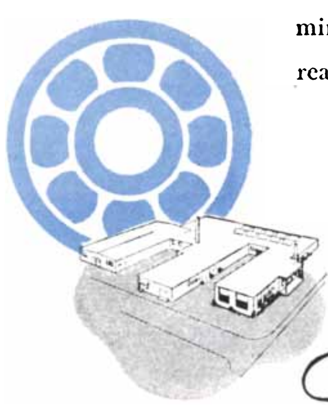

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THE COVER

The painting on the cover is a close-up of the apparatus used to study the behavior of an artificial muscle fiber (*see page 18*). The fiber is made by reducing natural muscle to its constituent protein molecules, allowing them to spread on the surface of a water-filled trough and squeezing them together. In the painting the fiber is suspended from the glass hook. At the bottom of the fiber is a glass weight. Below the weight is an arrangement by which it may be lifted or pulled down. The fiber is immersed in a solution to which can be added substances that cause contraction or relaxation. The small tank containing this solution is set within another through which water is circulated at constant temperature. At the edges of the painting is the cement of the larger tank. At the bottom of the tank is the shell of a clam, symbolizing the fact that some of the experiments use clam muscle protein.

THE ILLUSTRATIONS

Cover painting by Stanley Meltzoff

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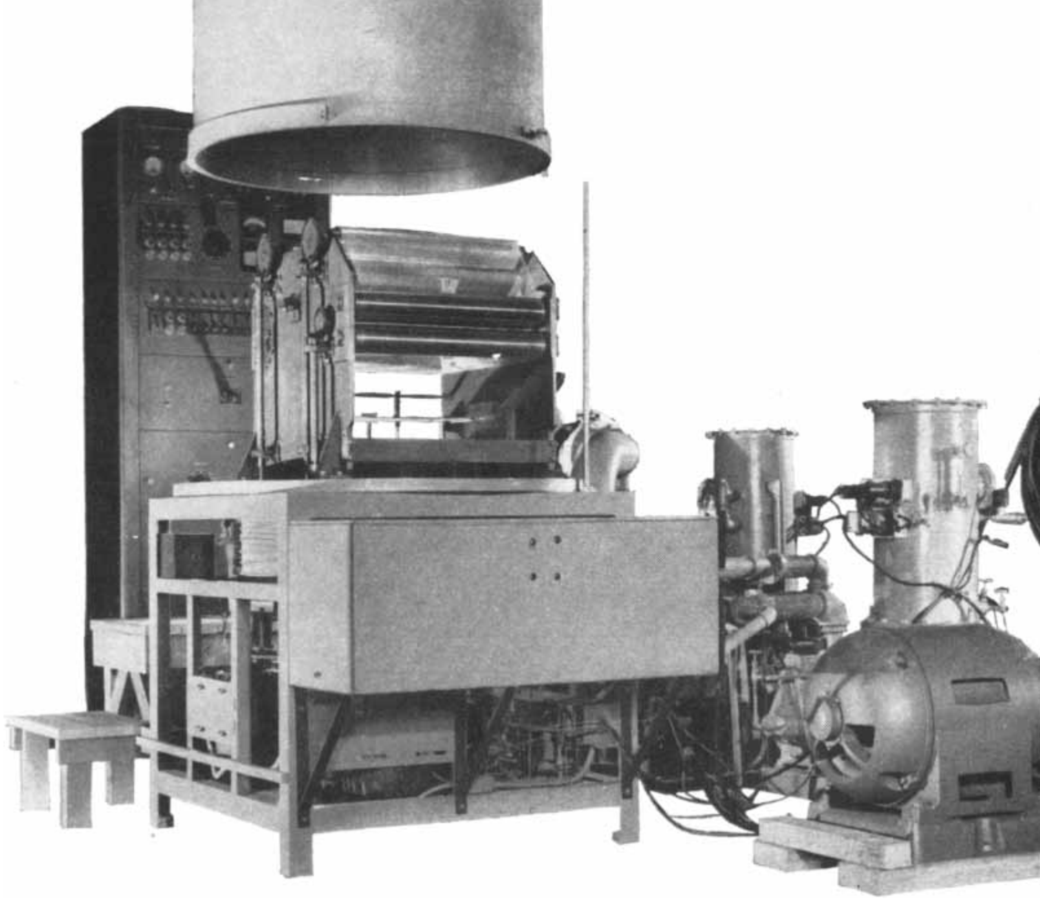
72	Irving Geis
85-90	Roger Hayward



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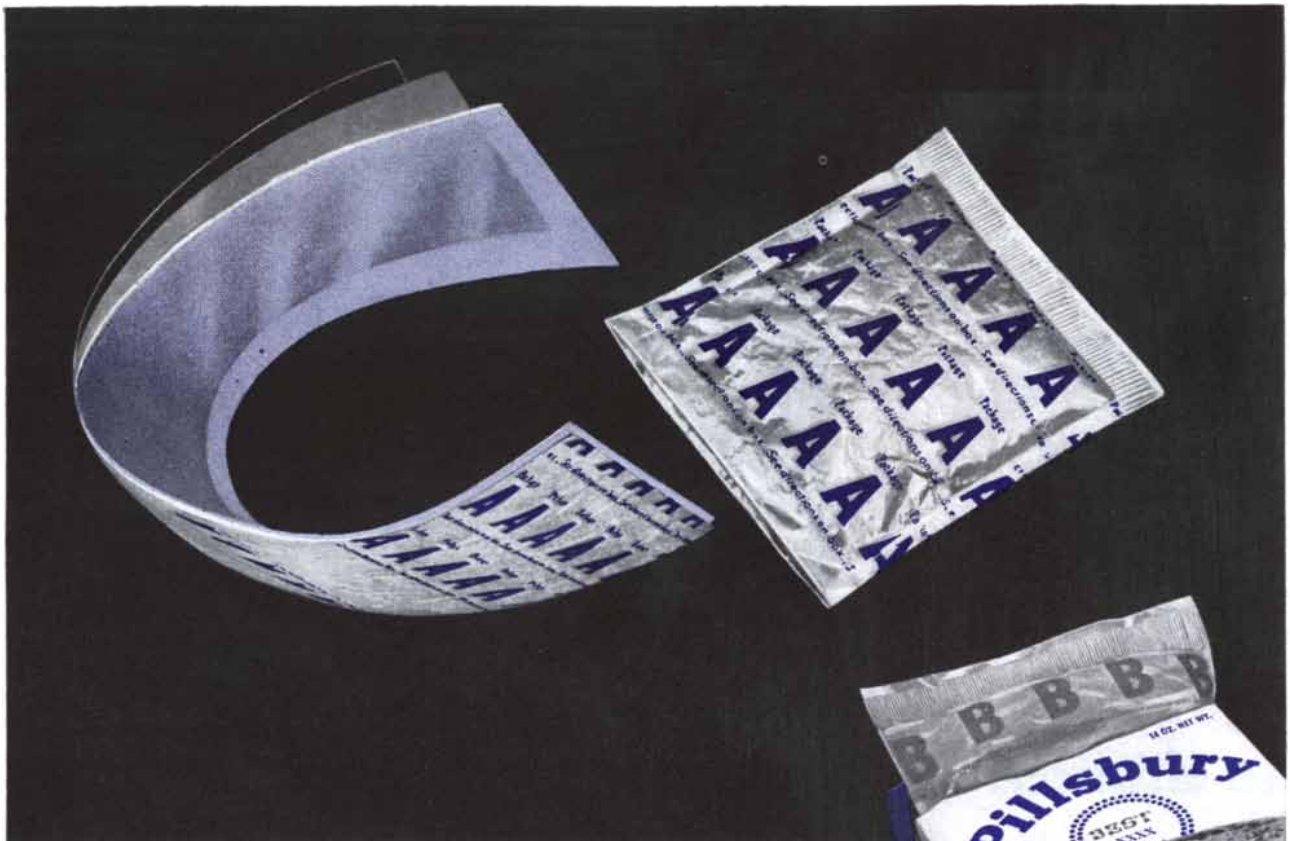

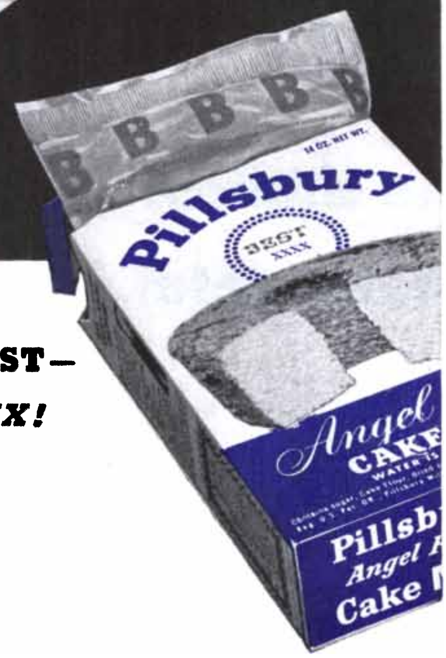

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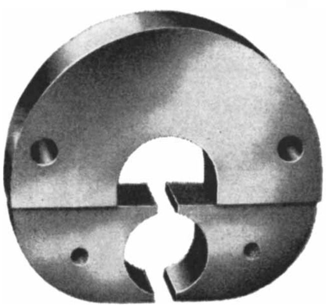
What's Happening at CRUCIBLE

about permanent alnico magnets

automatic control—permanent magnets are partners in industrial progress

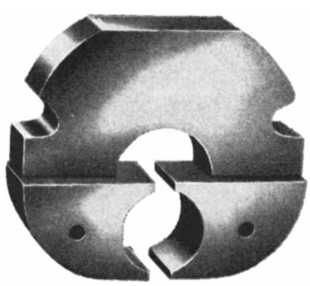
One important part of the "automatic" factory is the requirement that measuring devices be accurate, rugged . . . and because of their use in such great volume they have to be low cost. It is a credit to instrument manufacturers that these meter miracles are being accomplished. Not only are the meters more sensitive, lower cost . . . but specialized problems in measurement are solved everyday with new and different instruments.

Marion Meter, Model 53RN.



Former design of magnet assembly using Alnico II.

before



Note how redesigned magnet is made lighter because of reductions in area. The change from Alnico II to Alnico V with this design improved flux density.

after

here's how Marion cut magnet costs 1/3 ...and built a better meter!

Marion Electrical Instrument Company, prominent meter manufacturer, embarked on a plan of redesigning their meters to give improved service. The Marion Meter, Model 53RN shown here, is a good example of what is being accomplished.

In redesigning their instruments, Marion worked closely with Crucible magnet specialists. The recommendation was made to change from Alnico II to Alnico V for the magnetic alloy used in the meter's D'Arsonval movement. Then the magnet itself was redesigned. The overall effect was to reduce the weight of the magnet by 35%, cut the cost ⅓ . . . and increase the gap flux density which resulted in a 15% increase in the torque of the movement. The illustration shows the old and new design.

This development is typical of how Crucible is working to increase measuring efficiency with permanent alnico magnets. Have you a magnet application we can cut costs on by ⅓?

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SCIENTIFIC AMERICAN

DECEMBER, 1952 VOL. 187, NO. 6

The Useful Algae

Ranging from single cells to treelike colonies, these primitive plants support a whole hierarchy of marine life and also contribute directly to the needs of man

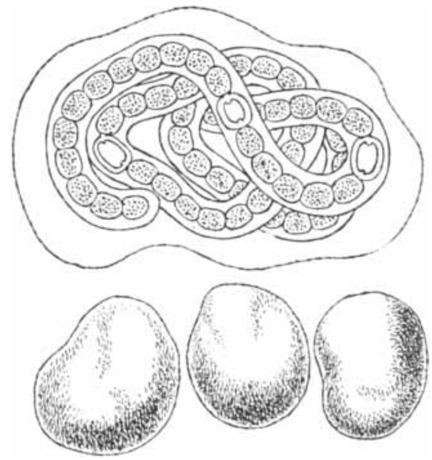
by Francis Joseph Weiss

When a manufacturer wishes to test the performance of new production methods without investing too much capital, he usually sets up a pilot plant—a flexible assembly of machinery which can be adjusted to a wide range of experimental conditions. Nature seems to have availed herself of the same device in developing some of the fundamental processes of life, such as food assimilation, respiration and reproduction. Her "pilot plant" was the alga, a simple plant most commonly known as seaweed. Algae are an ideal experimental setup. Most diverse and flexible of all the classes of organisms, they vary in size from microscopic single cells to the multicellular giant kelp, which is as big as a large tree, and they can adjust their living to extremes of environmental conditions, on land and in the sea. The algae have no special organs—no true roots, stems or leaves—yet the larger varieties do possess structures which, simple as they are, perform well-defined functions.

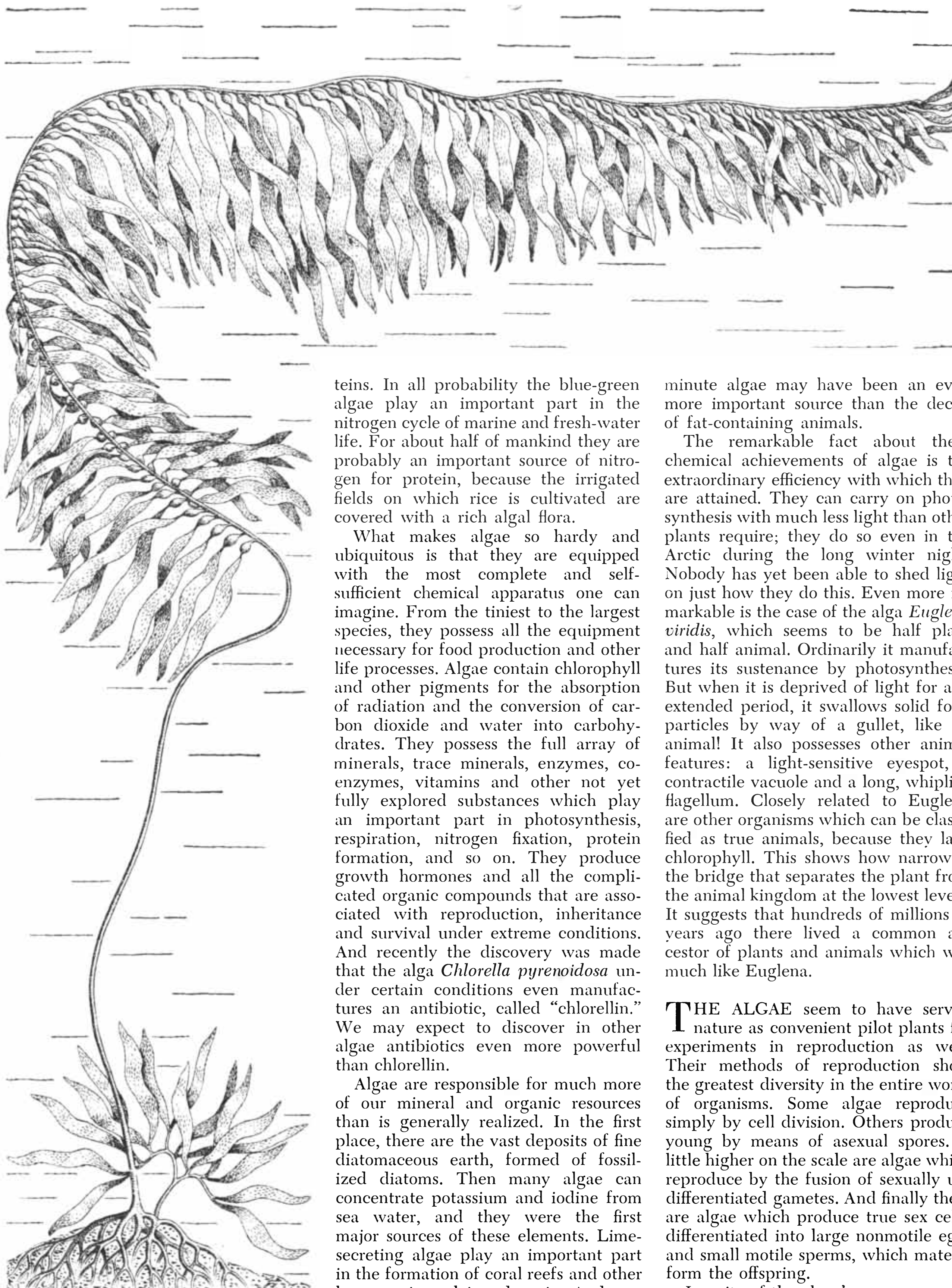
The most conspicuous and important function of these organisms is, of course, the conversion of inorganic matter into organic substance. Like all green plants, they transform carbon dioxide and water into living material by photosynthesis. It was the "invention" of photosynthesis by some simple alga or its precursor billions of years ago that made the evolution of life on this planet possible. The algae still account for most of the photosynthetic activity on the earth. There is about 10 times as much photosynthesis going on in the oceans as on land, and the enormous photosynthetic action in the oceans is almost entirely based upon the life process of algae. The greatest producers, in aggregate bulk, are the microscopic diatoms and dinoflagellates that live in the surface layers of the open seas. But there is also a vast production of organic matter by the larger green, brown and red algae, which grow off continental shores and in a few ocean areas such as the Sargasso Sea, which got its name from the brown alga *Sargassum natans* that floats over large stretches of this section of the Atlantic Ocean.

The minute algae that form the "grass of the sea" are the base of a food pyramid, the apex of which is occupied by fishes that serve as food for man. Algae are devoured by slightly larger protozoa; protozoa and algae are eaten by numerous tiny crustaceans; the crustaceans in turn serve as food for the herring, the most abundant fish of the ocean, and the herring finally is eaten by such carnivorous fish as cod, haddock and tuna. Not only are algae the first link in the food chain, but they also give a foothold to plant and animal life in places where one would think no life could exist, such as on bare rocks and cliffs, in hot springs at temperatures as high as 167 degrees Fahrenheit, in ice and snow, at the bottom of lakes and ponds, in dark caves, in the cells of protozoa and in the intestinal tracts of higher animals. In symbiotic association with fungi, algae form the large and widely distributed group of lichens, often the aboriginal stage in plant succession. In short, there is no more ubiquitous organism than the alga, and none that has had a more significant impact on life, past and present.

Man has made use of algae for thousands of years. The manna that fell from Heaven on the Israelites was in all probability a blue-green alga. The word manna was derived from the Hebrew *mân hu*, meaning "What is it?" From the accurate description of it in Exodus we know now that it must have been an alga species of the genus *Nostoc*. This plant grows with unbelievable rapidity during the night, with the aid of the heavy dew upon highly mineralized desert soils. If not harvested in the morning, as the Israelites were ordered to do, it melts away "when the sun waxes hot." It is also subject to fast decomposition by bacteria. Manna still grows in desert areas of California, Pakistan and China, and many people still eat it. The Nostoc algae are a nourishing food; not only can they synthesize carbohydrates with great efficiency but they are able to fix nitrogen from the air and use it in building pro-



ALGA of the genus *Nostoc* was probably the biblical manna. Top: Cross section. Bottom: Actual size of alga.



SEA KELP *Macrocystis pyrifera* grows in fronds. It is harvested on a large scale off the California coast.

teins. In all probability the blue-green algae play an important part in the nitrogen cycle of marine and fresh-water life. For about half of mankind they are probably an important source of nitrogen for protein, because the irrigated fields on which rice is cultivated are covered with a rich algal flora.

What makes algae so hardy and ubiquitous is that they are equipped with the most complete and self-sufficient chemical apparatus one can imagine. From the tiniest to the largest species, they possess all the equipment necessary for food production and other life processes. Algae contain chlorophyll and other pigments for the absorption of radiation and the conversion of carbon dioxide and water into carbohydrates. They possess the full array of minerals, trace minerals, enzymes, coenzymes, vitamins and other not yet fully explored substances which play an important part in photosynthesis, respiration, nitrogen fixation, protein formation, and so on. They produce growth hormones and all the complicated organic compounds that are associated with reproduction, inheritance and survival under extreme conditions. And recently the discovery was made that the alga *Chlorella pyrenoidosa* under certain conditions even manufactures an antibiotic, called "chlorellin." We may expect to discover in other algae antibiotics even more powerful than chlorellin.

Algae are responsible for much more of our mineral and organic resources than is generally realized. In the first place, there are the vast deposits of fine diatomaceous earth, formed of fossilized diatoms. Then many algae can concentrate potassium and iodine from sea water, and they were the first major sources of these elements. Lime-secreting algae play an important part in the formation of coral reefs and other large marine calcium deposits. And now it has been discovered that in the formation of the earth's great petroleum deposits the accumulation of tiny oil droplets in the cells of diatoms and other minute algae may have been an even more important source than the decay of fat-containing animals.

The remarkable fact about these chemical achievements of algae is the extraordinary efficiency with which they are attained. They can carry on photosynthesis with much less light than other plants require; they do so even in the Arctic during the long winter night. Nobody has yet been able to shed light on just how they do this. Even more remarkable is the case of the alga *Euglena viridis*, which seems to be half plant and half animal. Ordinarily it manufactures its sustenance by photosynthesis. But when it is deprived of light for any extended period, it swallows solid food particles by way of a gullet, like an animal! It also possesses other animal features: a light-sensitive eyespot, a contractile vacuole and a long, whiplike flagellum. Closely related to Euglena are other organisms which can be classified as true animals, because they lack chlorophyll. This shows how narrow is the bridge that separates the plant from the animal kingdom at the lowest levels. It suggests that hundreds of millions of years ago there lived a common ancestor of plants and animals which was much like Euglena.

THE ALGAE seem to have served nature as convenient pilot plants for experiments in reproduction as well. Their methods of reproduction show the greatest diversity in the entire world of organisms. Some algae reproduce simply by cell division. Others produce young by means of asexual spores. A little higher on the scale are algae which reproduce by the fusion of sexually undifferentiated gametes. And finally there are algae which produce true sex cells, differentiated into large nonmotile eggs and small motile sperms, which mate to form the offspring.

In spite of the algae's enormous variability in form and function, they are, generally speaking, a very conservative group of organisms. They do not exhibit that unquenchable urge for progress which we suppose to be inherent in every living being. As far as the earliest geological records of their existence allow us to see, they have not changed much in either form or life activities; some species of today may well be identical with ancestors that lived in the Archeozoic sea about 1.2 billion years ago. While other members of the animal and plant kingdoms branched out into highly differentiated forms, the main classes of algae (blue-green, yellow-green, green, red and brown) went their simple ways. Perhaps this is due to the fact that their ocean environment remained essentially unchanged and at the same time provided them with ever more ample food. The constant erosion and leaching of minerals from the land into the oceans during hundreds of millions of years has vastly enriched the seas' mineral content. Since algae have an extraordinary capacity to accumulate minerals, they have become steadily richer in sodium, potassium, calcium, magnesium, chlorine, sulfur, iron, copper, manganese, zinc, arsenic, cobalt, nickel, lead, tin, molybdenum, antimony, titanium, boron, bromine and iodine.

Algae of marine origin, therefore, make excellent fertilizers for depleted soils. They can supply minerals, especially the trace elements, whose essential function in plant and animal life has been emphasized by recent investigations. The incorporation of algae or algal products into fertilizers would not add a strange factor to the soil. Indeed, terrestrial algae play an essential part in maintaining soil fertility: they bind soluble mineral and nitrogen compounds into organic forms and prevent leaching losses; they decompose organic matter; they help in nitrogen fixation; they contribute to the aeration of the root system by absorbing carbon dioxide and giving off oxygen, and finally, they form stable colloidal systems, which have a most beneficial effect upon soil texture. As a matter of fact, the alginic acid of brown algae resembles the recently synthesized soil conditioner called Krilium.

FARMERS have used some seaweeds, especially the large brown algae, as fertilizer and fodder since ancient times. In certain coastal areas of Norway sheep are fed exclusively on seaweed. In Scotland cattle and sheep often wander down to the shore and graze on seaweeds in preference to pastures. On the Pacific Coast of the U. S. several factories have been established to make cattle-feed from seaweed. Recently the Overbrook dairy herd, 10 per cent of whose feed ration was dried seaweed, set a world's record in milk production. On the west and southwest coast of Ireland seaweed is extensively used as manure for potato fields. Peasants think so highly of its fertilizing value that they carry it as far as eight miles inland.

Since time immemorial the larger seaweeds have served human beings as a food supplement. Millions of people in the densely populated areas along the Pacific coast of Asia and on Pacific islands—Chinese, Japanese, Indonesians, Filipinos, Hawaiians, Burmese—eat seaweed today, using some 100 different species of it. According to J. P. Harrington the aboriginal Indians of North America fed on the red alga *Porphyra tenera*, which grows abundantly on the Gulf of Alaska and on the shores of British Columbia, Washington, Oregon and California. On the coast of what is now Peru and Chile the early Indians found immense growths of the large brown alga *Durvillea antarctica*, the succulent stipe of which makes a nourishing dish. This plant still is a popular food in southern Chile, where it is called *cochayuyo*, an Inca name meaning "sea cabbage." It is reported that Chileans who supplement their diet with seaweed are healthier than those who do not.

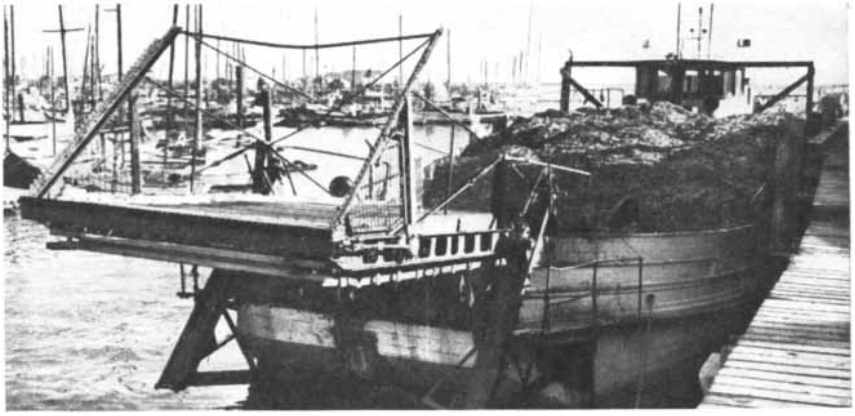
New Englanders like to prepare puddings from the gelatinous fronds of the red alga *Chondrus crispus*, known as "Irish moss."

Now it is true that the caloric value of seaweed dishes is low, that their carbohydrate has poor digestibility, that their proteins lack some essential amino acids and that their fat content is very small. But they are rich in minerals and certain vitamins, and, most important, can supply the bulk that is lacking in refined modern foods. In the absence of bulk, the flow of the contents of the intestines becomes sluggish, leading ultimately to constipation. The gelatinous substances of algae provide excellent roughage. They stimulate the peristaltic movements, facilitate elimination and give a feeling of satiation and well-being. They should be especially suitable for reducing diets and for patients who are suffering from constipation.

The remarkable algae contain several substances which are just now of great interest to chemists—notably agar and algin. Algin, the sodium salt of alginic acid, is a gelatinous compound analogous to pectin. It is found in large amounts in all the brown algae or seaweeds, and can easily be extracted. Algin and its derivatives have a great number of present and potential uses in industrial and food chemistry. Algin can be pressed into boards or other plastic products. Its mineral salts can be spun into noninflammable fibers. Algin makes many food products more appealing and palatable. It is estimated that no less than 75 per cent of all the ice cream consumed in the U. S. is now emulsified with algin. In addition it is used as a stabilizer in sherbets, chocolate milk and cheese and as a thickener for soups and salad dressings. And in the industrial field algin is widely used in pharmaceutical emulsions, cosmetic preparations, sizing material, paper coating, paints and varnishes, latex creaming, leather finishing—in short wherever need exists for a gel-forming hydrophilic substance.

WITH all this, the possibilities of the algae have scarcely been touched so far. I can only mention here the work being done with the tiny green algae of the genus Chlorella, for that is a big story in itself. The promising prospect of growing these single-celled algae under controlled conditions for the production of synthetic food on a vast scale is already being tested in pilot plants. Thus the algae, which started out as pilot plants of Nature, are now serving as pilot plants of Man, who will doubtless get equally important results—and far more speedily.

Francis Joseph Weiss, biochemist, was the author of "Chemical Agriculture," which appeared in the August issue of this magazine.

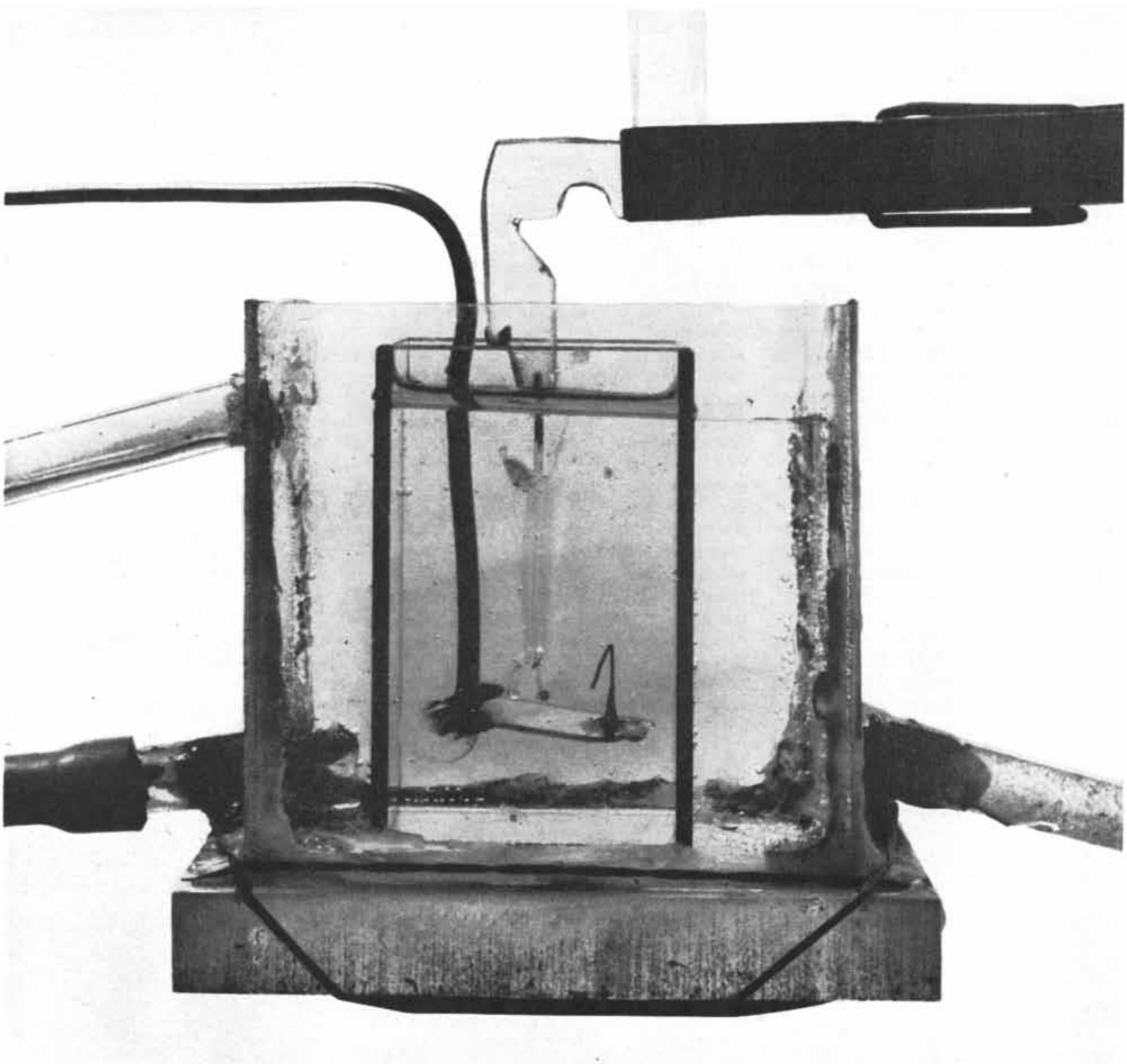


KELP HARVESTER docks at San Pedro, Calif., with a cargo of *Macrocystis pyrifera*. The kelp is now dehydrated. About 90 per cent of its dry weight is water; of the remaining 10 per cent a third is minerals.

Artificial Muscle

What is the mechanism of muscular contraction? A promising new approach to the problem involves reducing the tissue to its constituent molecules and putting them together again

by Teru Hayashi and George A. W. Boehm



ARTIFICIAL MUSCLE FIBER is suspended from a hook in the center of this photograph. The fiber is immersed in a solution to which may be added substances that cause contraction. At the bottom end of the fiber is a glass weight. Beneath the weight is an arrangement that may be employed to lift or stretch the fiber.

NO MECHANIC, however ingenious, could hope to build a working model of a muscle. The merest twitch of an eyelid is actuated by a mechanism far too complex, yet at the same time too beautifully simple, to be simulated by any contraption of bolts, cams, gears, springs, or the like. An electronic servo-mechanism might in its introspective way behave like a muscle, but even such a device, swift and sensitive as it might be, would seem a clumsy plodder beside the compact, lightning-fast living muscle. We have here a chemical machine which is more elegant than any that electronics or mechanics could ever create, and to build its match we must look to chemistry itself.

On casual inspection a strip of muscle seems very like a rubber band. Closer scrutiny under a microscope discloses a structure resembling that of an elastic garter: it has fibers running the length of the strip and striped with transverse lines. These fibers, or their component fibrils and filaments, are thought to be the muscle's contracting elements, just as in a garter. But there the similarity between muscle and ordinary elastics ends. Unlike a merely elastic material, muscle tissue can harden abruptly, alter its shape, lift hundreds of times its own weight and return to jelly-like flabbiness when it relaxes. Moreover, it can repeat this whole process scores of times a second.

When it comes to understanding how muscle performs its prodigious feats, biologists are still groping in dim light. The history of muscle research is spangled with impressive names and intriguing ideas, but no single approach has succeeded in explaining muscle action completely. The anatomist has studied its peculiar crosswise striations and, with the aid of the electron microscope, resolved the lengthwise fibers into bundles of slenderer fibrils. The physiologist has measured the force and speed of muscular contraction and examined the nerve-actuated bio-electric events which initiate the change from jelly to taut tissue. The biochemist has ground muscle to paste, centrifuged it and separated it into its various components, then determined how these chemical fragments react. But all these researches still lack unifying ideas. Muscle structure does not explain muscle action. Measurements of muscle action fail to make clear the source of energy. And biochemical reactions in the cells of the muscle tissues have still not been correlated with the structural changes in the fibers that bring about contraction.

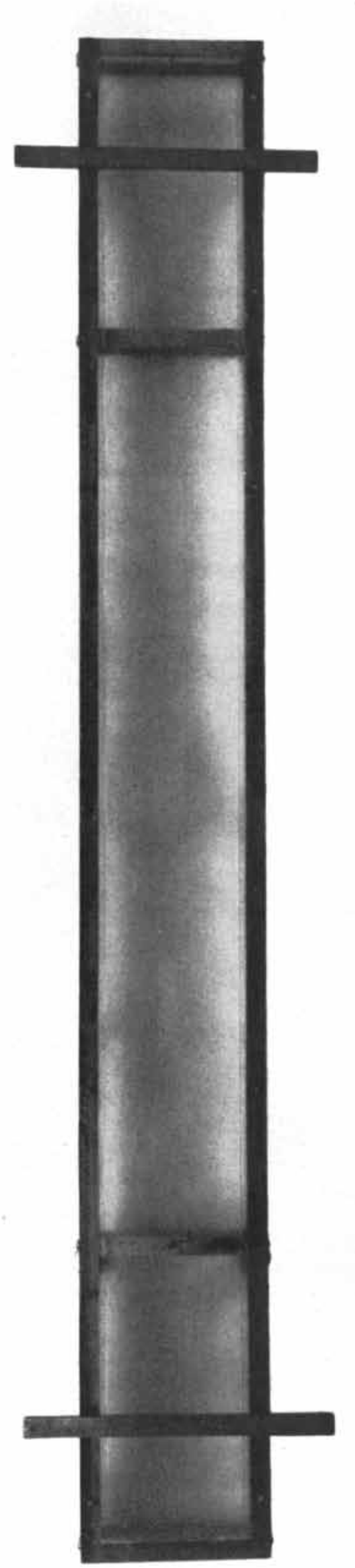
In recent years these three basic approaches to muscle have been combined in a fourth: an attempt to create "artificial" muscle, or rather, to reconstruct muscle from gross chemical parts. No artificial muscle so far synthesized has been more than a feeble impostor. But little by little this synthetic tissue is becoming more muscular.

THE MAIN line of investigation into the chemistry of muscle has stemmed from a discovery made in 1868 by the German biochemist Willy Kühne. He extracted from muscle tissue a substance which he named "myosin." It was thought to be a single protein. No one did much with this discovery until 1934, when the German investigator Hans H. Weber succeeded in forming from Kühne's "myosin" some thread-like fibers. He did this by squirting a thin stream of the dissolved protein into water; the protein precipitated in the form of a slender string. Five years later the Russian biochemists V. A. Engelhardt and M. N. Ljubimova discovered that "myosin" is an active factor in the release of energy in a biochemical system. It reacts with and splits the energy-bearing compound adenosine triphosphate (ATP), which is present in all living systems and is especially abundant in muscle. Shortly afterward the Hungarian worker F. B. Straub found that Kühne's "myosin" was not a single substance but a combination of two proteins, which he named actin and myosin. The combination was rechristened actomyosin.

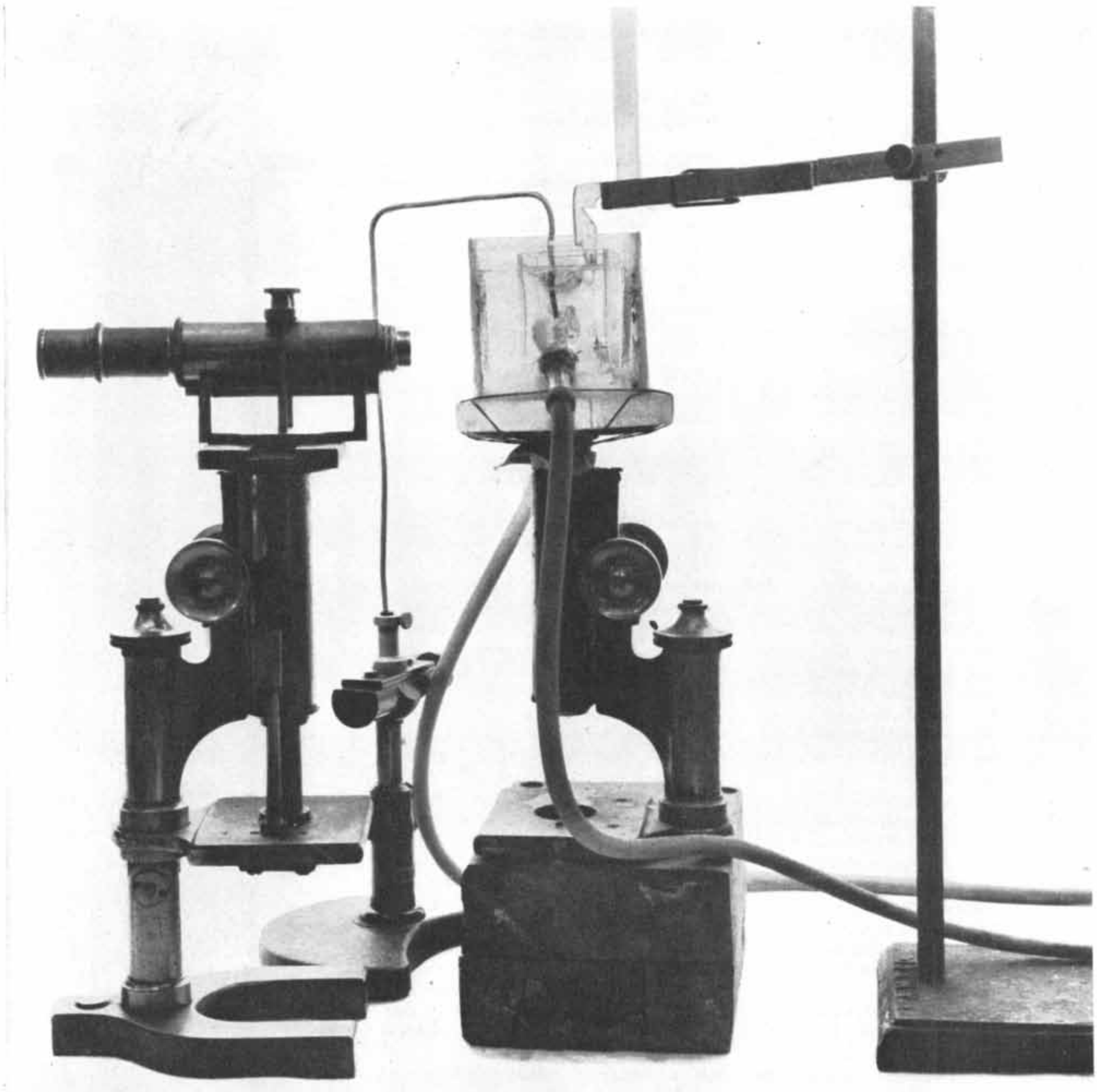
All this set the stage for a striking experiment in 1941 by the Hungarian-born biochemist Albert Szent-Györgyi. He immersed precipitated actomyosin fibers of the Weber type in a solution of potassium salt and ATP, and when he did so, the fibers contracted! After the war Szent-Györgyi continued his experiments with actual muscle fibers taken intact from animals. He froze and washed the fibers, removing the ATP they contained. Without this energy-yielding compound they were, of course, powerless to contract. But Szent-Györgyi found that when they were put in a salt-ATP solution, they did contract, just as his actomyosin fibers had.

His findings electrified muscle physiologists and stimulated new experiments in laboratories all over the world. Szent-Györgyi proposed that this "mechanochemical" reaction which he had demonstrated might be the basis of living muscles' activity. Here was a chemical reaction, involving substances known to be present in muscle, which transformed chemical energy into mechanical work.

Yet the reaction was only superficially like natural muscle contraction. The Weber-type precipitated fibers that Szent-Györgyi had used refused to do any work: when loaded, even lightly, they sagged instead of tensing. Apparently the molecules in them, though contracting individually, were not tied



LANGMUIR TROUGH is seen from above. A film of muscle protein on its surface is squeezed together by rods.



FIBER IS OBSERVED through a low-powered microscope. The movement of the weight at the bottom of the fiber is measured by a vernier scale on the side of the microscope stand. The tank in which the fiber is immersed is surrounded by another through which water is circulated to control the temperature during experiments.

together in a continuous molecule-to-molecule chain that would be able to support and lift a load. The fibers lacked orientation and organization.

IN 1949 a group of workers in the biophysics laboratory of the zoology department at Columbia University became interested in this problem. The group had been intrigued by the fact that the living cell contains a hodgepodge of substances, many of which are as incompatible as oil and water. This means, of course, that in the cell there are many interfaces between the nonmixing substances. Now it is well known that protein molecules, upon coming into contact with such an interface, tend to spread over the surface. That is to say, the protein reacts with the surface and is physically changed from a more or less spherical molecule to a flat, sheetlike structure which becomes insoluble in water. The Columbia group felt that such a process might account for the formation of some of the active structures in the cell.

They were encouraged in this idea by some of their experiments. It had been thought that proteins lost their biological activity when they reacted with a surface. But the Columbia workers showed that certain enzyme molecules not only retained their activity when surface-spread but also showed the same characteristic behavior in the artificial experimental situation as they did in the cell. To a research team armed with these facts, actomyosin seemed to be an ideal material for investigation. It is a protein, an enzyme capable of releasing energy from ATP, and it forms a structure within the muscle cell—the long fibrils.

The Columbia biophysicists proceeded to apply these ideas to form artificial muscle fibers in a new way. First they formed a film of surface-spread actomyosin molecules on the surface of a dilute potassium salt solution. They did this in the following manner: The salt solution filled a brimming box, known as a Langmuir trough. To the surface of the liquid they touched a slide on which was deposited some actomyosin in solution. The actomyosin promptly spread over the surface to form a uniform film. After the actomyosin molecules had settled into an orderly array, the experimenters skimmed the top of the brimming trough with two chromium rods, pushed toward each other from both sides. This pressed the film together like an accordion, and it was compressed into the shape of a string. The resulting thread, made of clear, colorless protein, consists of continuous lengthwise fibers, like muscle.

The Columbia group then contrived an apparatus to test how closely the properties of their artificial fiber approached those of natural muscle (*see photograph on opposite page*).

THE FIRST challenge confronting artificial muscle is: Can it transform chemical energy into work? To test this the researchers tied one end of their fiber to an overhead hook and the other end to a weight in the form of a bent sliver of glass. Knotting the frail and slippery protein thread requires a surgeon's dexterity; it has been one of the research group's most difficult accomplishments. When the fiber, thus weighted, was immersed in a weak potassium chloride solution fortified with ATP, it contracted and pulled up the glass weight. The rise of the weight is small; it has to be measured with the aid of a vernier scale mounted on a low-powered microscope. In 15 to 20 minutes a typical one-inch length of artificial muscle will have shortened by almost one quarter of an inch and in so doing will have hoisted 100 times its own dry weight. This demonstration that the fibers can do work shows that the component actomyosin molecules have been hitched together in a continuous structure.

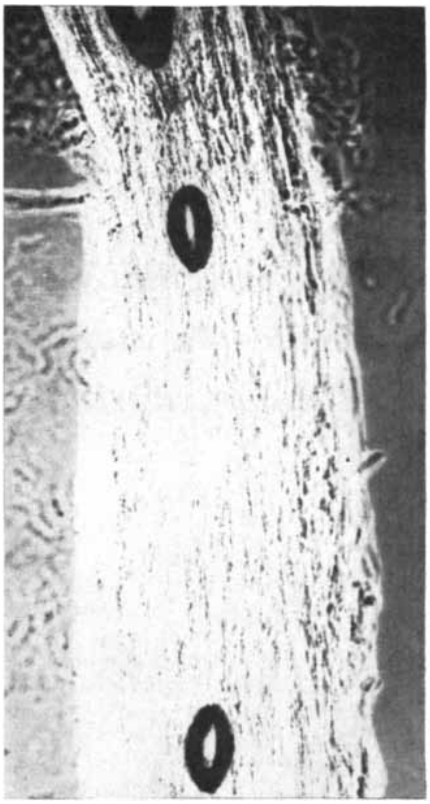
Having proved that their protein strings can lift a load, the Columbia researchers then showed that the fibers also can relax. They replaced the bath of ATP and diluted salt with a more concentrated solution of salt, with or without ATP. In the concentrated salt solution the weighted fiber slowly stretched until it attained its original length. By alternating the strong and the weak salt solutions, the experimenters can make their artificial muscle relax and contract again and again.

One of the most fascinating properties of muscle is its ability to rise to an occasion. That is, the heavier the load placed on it, the more work it will do, within limits, of course. As the load increases, the muscle is stimulated to work harder to contract and lift it. This phenomenon poses subtle questions in muscle physiology, and the underlying mechanisms are still the subject of research and debate. The experiments to date with the artificial actomyosin fibers show that they do more mechanical work on a heavier load than on a lighter one—mechanical work being measured as the weight of the load multiplied by the distance it is lifted.

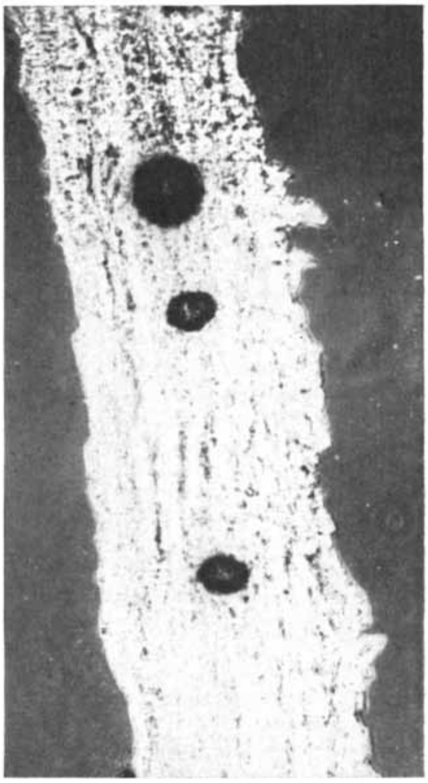
There is no proof as yet that the contractions of these artificial muscles are induced by precisely the same reaction with ATP as in natural muscle, although the surface-spread actomyosin does show the ability to split ATP, thus releasing chemical energy. The artificial fibers show one obvious difference from natural muscle; they react much more slowly. It takes them several minutes to contract, whereas natural muscle does so in a fraction of a second. Perhaps in the artificial muscle the actomyosin molecules are imperfectly aligned, leaving weaknesses in their ideally continuous structure. And obviously they lack the electric nerve impulses that trigger contraction in natural muscle.

IF THESE dissimilarities can be satisfactorily explained, and if enough similarities to living muscle can be established, the artificial muscle fibers may become a powerful tool for finding out how the living muscle works. They may throw light on such important questions as how the protein chains kink to produce shortening, and the precise nature of the reaction that transforms chemical energy into mechanical work. As a matter of fact, the artificial muscle may already have provided the answer to one key question. For several years investigators have debated whether muscle relaxation is an active or passive reaction. In other words, can an unloaded muscle elongate by pushing itself out, or must it be stretched by a weight? The answer seems to be that relaxation is passive, at least insofar as the artificial fibers represent muscle. Even in a relaxing solution of concentrated potassium chloride a contracted fiber does not stretch unless it is loaded.

Teru Hayashi is associate professor of zoology at Columbia University. George A. W. Boehm is a science writer whose articles have previously appeared in this magazine.



UNCONTRACTED FIBER is indicated by the relative position of the three air bubbles inside of it.



CONTRACTED FIBER is indicated when the same three bubbles are closer together and flattened.

The Curious Behavior of the Stickleback

This insignificant fish has a ceremonious sex life. To attract females the male builds a house, changes color and does a kind of dance, a ritual singularly useful to the study of instinct

by N. Tinbergen

When I was a young lecturer in zoology at the University of Leyden 20 years ago, I was asked to organize a laboratory course in animal behavior for undergraduates. In my quest for animals that could be used for such a purpose, I remembered the sticklebacks I had been accustomed as a boy to catch in the ditches near my home and to raise in a backyard aquarium. It seemed that they might be ideal laboratory animals. They could be hauled in numbers out of almost every ditch; they were tame and hardy and small enough to thrive in a tank no larger than a hatbox.

I soon discovered that in choosing these former pets I had struck oil. They are so tame that they submit unfrightened to laboratory experiments, for the stickleback, like the hedgehog, depends on its spines for protection and is little disturbed by handling. Furthermore, the stickleback turned out to be an excellent subject for studying innate behavior, which it displays in some remarkably dramatic and intriguing ways. We found it to be the most reliable of various experimental animals that we worked with (including newts, bees, water insects and birds), and it became the focus of a program of research in which we now use hundreds of sticklebacks each year. The stickleback today is also a popular subject in various other zoological laboratories in Europe, notably at the universities in Groningen and Oxford. To us this little fish is what the rat is to many American psychologists.

My collaborator J. van Iersel and I have concentrated on the stickleback's courtship and reproductive behavior. The sex life of the three-spined stickleback (*Gasterosteus aculeatus*) is a complicated pattern, purely instinctive and automatic, which can be observed and manipulated almost at will.

In nature sticklebacks mate in early spring in shallow fresh waters. The mating cycle follows an unvarying ritual, which can be seen equally well in the natural habitat or in our tanks. First each male leaves the school of fish and stakes out a territory for itself, from which it will drive any intruder, male or female. Then it builds a nest. It digs a shallow pit in the sand bottom, carrying the sand away mouthful by mouthful. When this depression is about two inches square, it piles in a heap of weeds, preferably thread algae, coats the material with a sticky substance from its kidneys and shapes the weedy mass into a mound with its snout. It then bores a tunnel in the mound by wriggling through it. The tunnel, slightly shorter than an adult fish, is the nest.

Having finished the nest, the male suddenly changes color. Its normally inconspicuous gray coloring had already begun to show a faint pink blush on the chin and a greenish gloss on the back and in the eyes. Now the pink becomes a bright red and the back turns a bluish white.

In this colorful, conspicuous dress the male at once begins to court females. They, in the meantime, have also become ready to mate: their bodies have grown shiny and bulky with 50 to 100 large eggs. Whenever a female enters the male's territory, he swims toward her in a series of zigzags—first a sideways turn away from her, then a quick movement toward her. After each advance the male stops for an instant and then performs another zigzag. This dance continues until the female takes notice and swims toward the male in a curious head-up posture. He then turns and swims rapidly toward the nest, and she follows. At the nest the male makes a series of rapid thrusts with his snout into the entrance. He turns on his side as he does so and raises his dorsal spines toward his mate. Thereupon, with a few strong tail beats, she enters the nest and rests there, her head sticking out from one end and her tail from the other. The male now prods her tail base with rhythmic thrusts, and this causes her to lay her eggs. The whole courtship and egg-laying ritual takes only about one minute. As soon as she has laid her eggs, the female slips out of the nest. The male then glides in quickly to fertilize the clutch. After that he chases the female away and goes looking for another partner.

One male may escort three, four or even five females through the nest, fertilizing each patch of eggs in turn. Then his mating impulse subsides, his color darkens and he grows increasingly hostile to females. Now he guards the nest from predators and "fans" water over the eggs with his breast fins to enrich their supply of oxygen and help them to hatch. Each day the eggs need more oxygen and the fish spends more time ventilating them. The ventilating reaches a climax just before the eggs hatch. For a day or so after the young emerge the father keeps the brood together, pursuing each straggler and bringing it back in his mouth. Soon the young sticklebacks become independent and associate with the young of other broods.

To get light on the behavior of man, particularly his innate drives and conflicts, it is often helpful to study the elements of behavior in a simple animal. Here is a little fish that exhibits a complicated pattern of activities, all dependent on simple stimuli and drives. We have studied and analyzed its behavior by a large number of experiments, and have learned a good deal about why the stickleback behaves as it does.

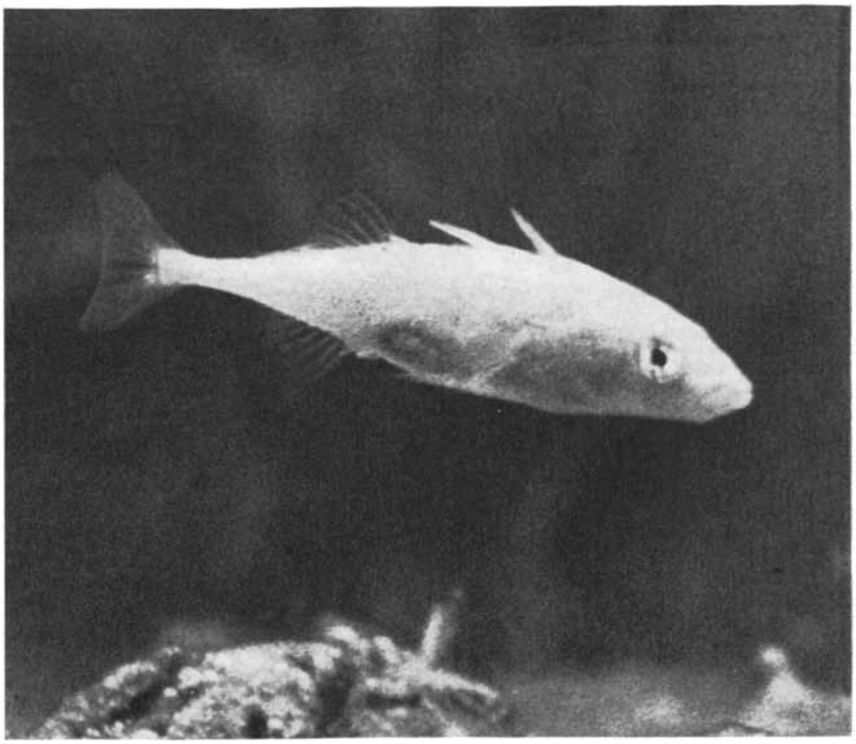
Let us begin with the stimulus that

causes one stickleback to attack another. Early in our work we noticed that a male patrolling its territory would attack a red-colored intruder much more aggressively than a fish of some other color. Even a red mail van passing our windows at a distance of 100 yards could make the males in the tank charge its glass side in that direction. To investigate the reactions to colors we made a number of rough models of sticklebacks and painted some of the dummies red, some pale silver, some green. We rigged them up on thin wires and presented them one by one to the males in the tank. We found that the red models were always more provoking than the others, though even the silvery or green intruders caused some hostility.

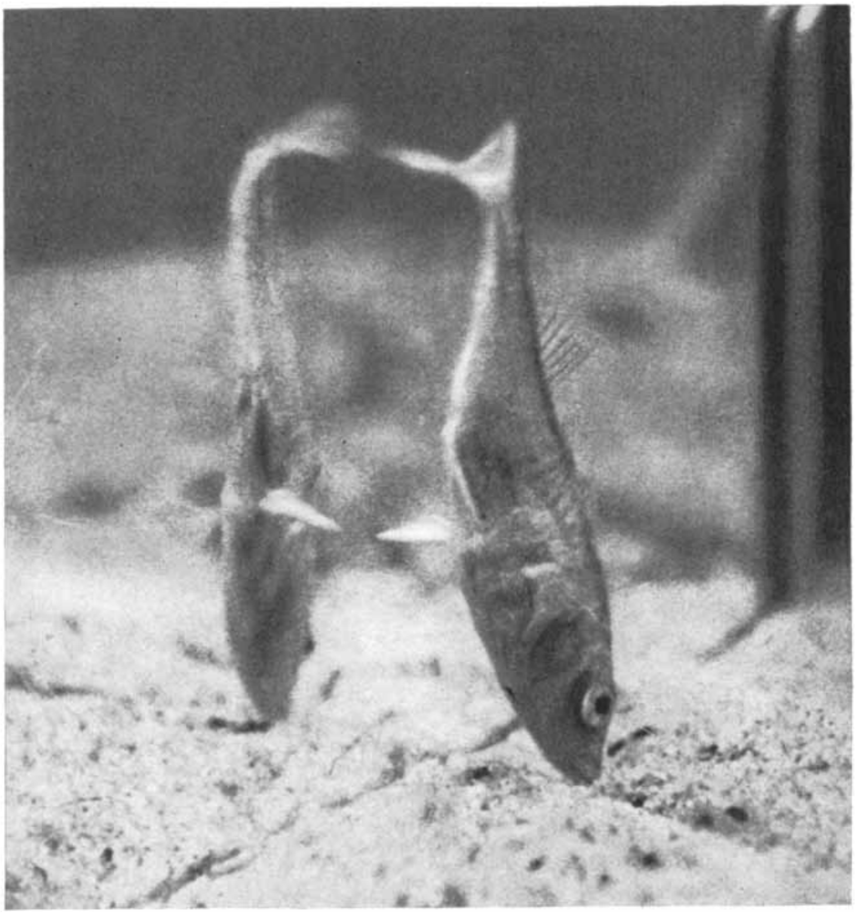
In much the same way we tested the influence of shape, size, type of body movement and other stimuli, relating them to specific behavior in nest building, courting, attack, zigzag, fanning and so on. We discovered, for example, that a male swollen with food was courted as if it were a female.

As our work proceeded, we saw that the effective stimuli differed from one reaction to another, even when two reactions were caused by the same object. Thus a female will follow a red model wherever it leads; she will even make frantic efforts to enter a non-existent nest wherever the model is poked into the sand. Once she is in a real nest, she can be induced to spawn merely by prodding the base of her tail with a glass rod, even after she has seen the red fish that led her there removed. At one moment the male must give the visual signal of red; at the next, this stimulus is of no importance and only the tactile sensation counts. This observation led us to conclude that the stickleback responds simply to "sign stimuli," *i.e.*, to a few characteristics of an object rather than to the object as a whole. A red fish or a red mail truck, a thrusting snout or a glass rod—it is the signal, not the object, that counts. A similar dependence on sign stimuli, which indicates the existence of special central nervous mechanisms, has been found in other species. It seems to be typical of innate behavior, and many social relationships in animals apparently are based on a system of signs.

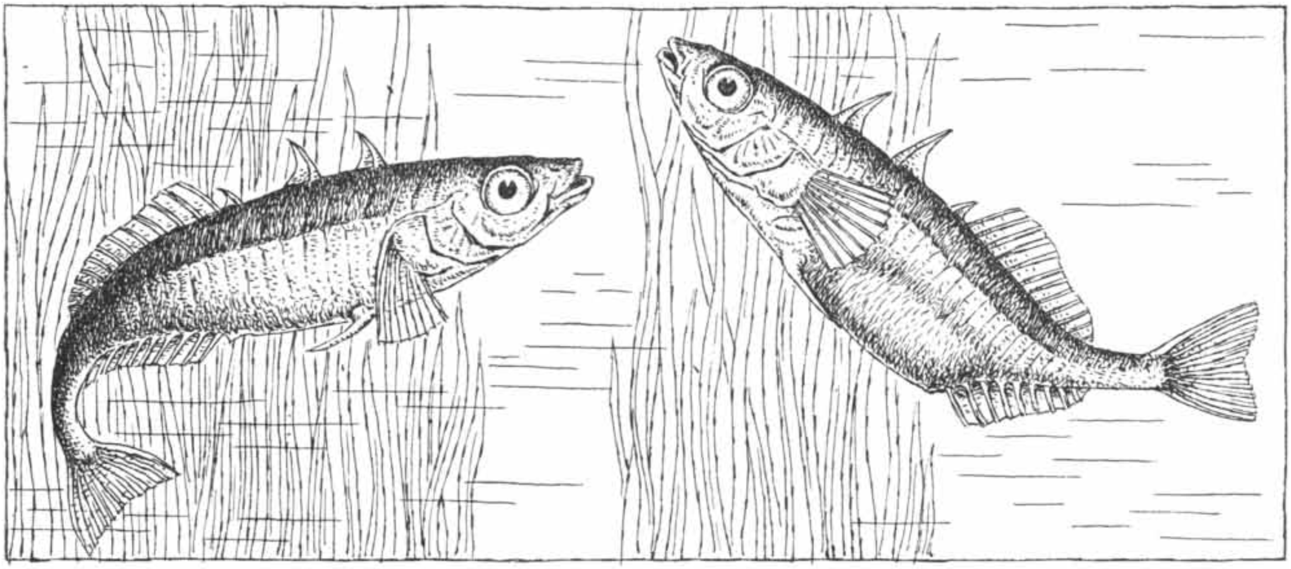
Sticklebacks will respond to our stimuli only when they are in breeding condition. At other seasons they ignore the signs. This fact led us to investigate the internal factors that govern the fish. The obvious way to study such fluctuations is to measure the frequency and intensity of a response under standard stimulation. For some of these tests we used either uniform models or live fish confined in glass tubes so that we could control their movement. To measure the parental drive we adopted the standard of the number of seconds spent in fan-



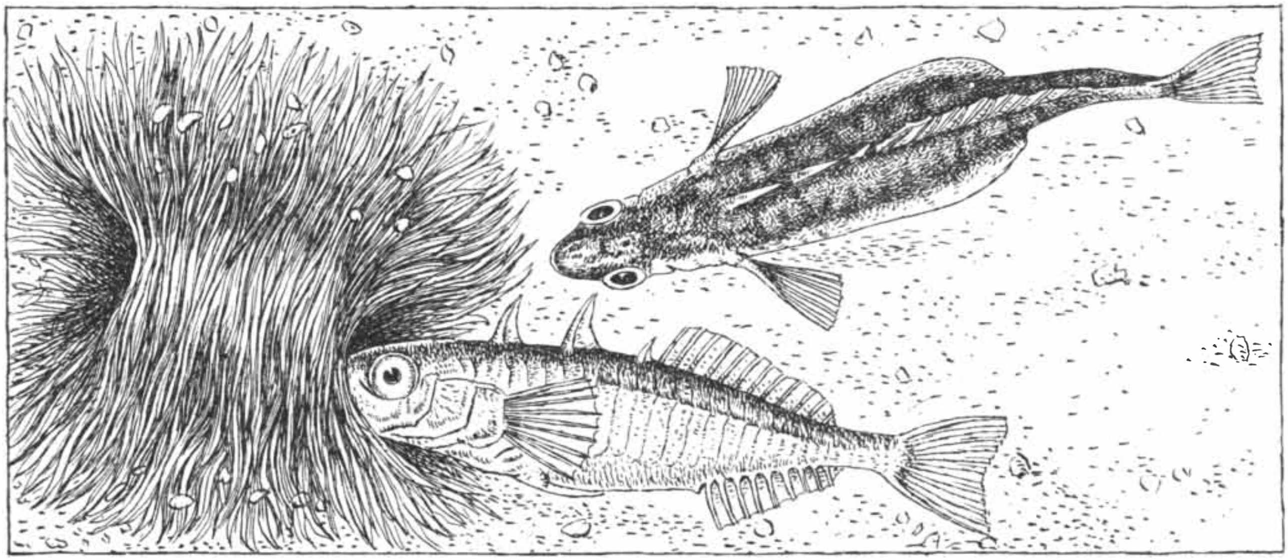
MALE STICKLEBACK (*Gasterosteus aculeatus*) **is photographed in full sexual markings. Its underside is a bright vermilion; its eyes, blue.**



MALE STICKLEBACK DIGS in the sand after it has perceived its image in a mirror. This is one aspect of its behavior during a fight with another male.



IN FIRST STAGE of courtship the male stickleback (*left*) zigzags toward the female (*right*). The female then swims toward him with her head up. The abdomen of the female bulges with from 50 to 100 eggs.



IN SECOND STAGE, seen from above, the male stickleback swims toward the nest he has built and makes a series of thrusts into it with his snout. He also turns on his side and raises his dorsal spines toward the female.

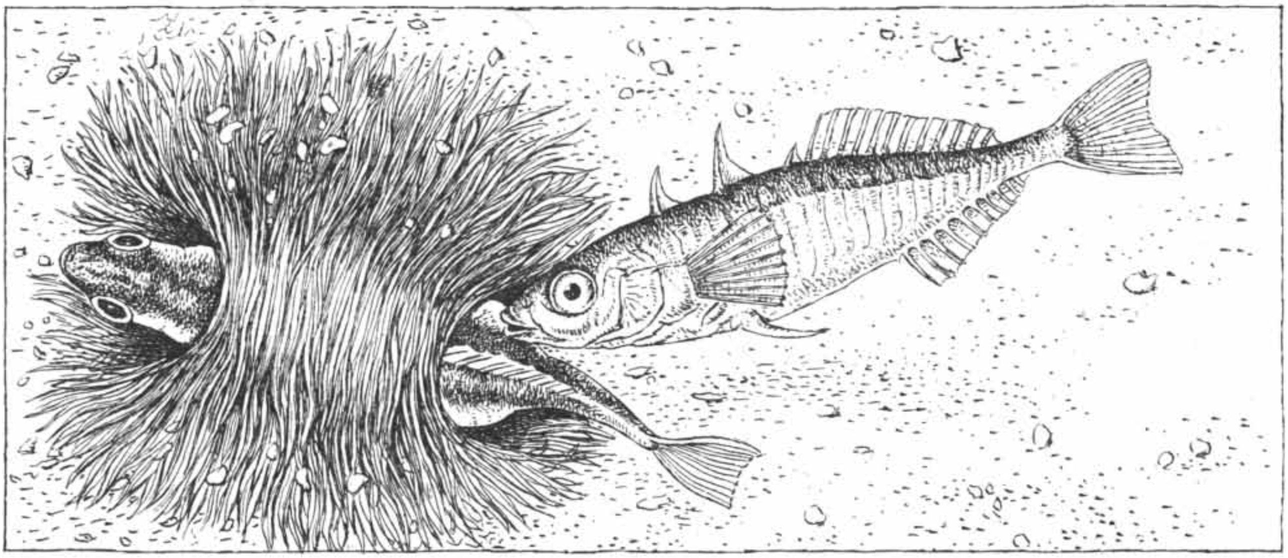
ning a given number of eggs per time unit.

The stickleback's drives in the breeding sequence wax and wane in a series of cycles. Each drive runs its course in regular succession: first the male gets the urge to fight, then to build a nest, then to court a female, then to develop the brood. He will not start to build, even though material is available, until he has defended his territory for a while. Nor will he court until he has built the nest; females that approach him before the nest is finished are driven off or at best are greeted with a few zigzags. Within each cycle also there is a fixed rhythm and sequence; for example, if you fill up the pit the male has dug, he will dig one again before collecting nest material. After the pit has been filled several times, however, the fish will build the nest without completing the pit. The development of his inner drive overcomes outside interference.

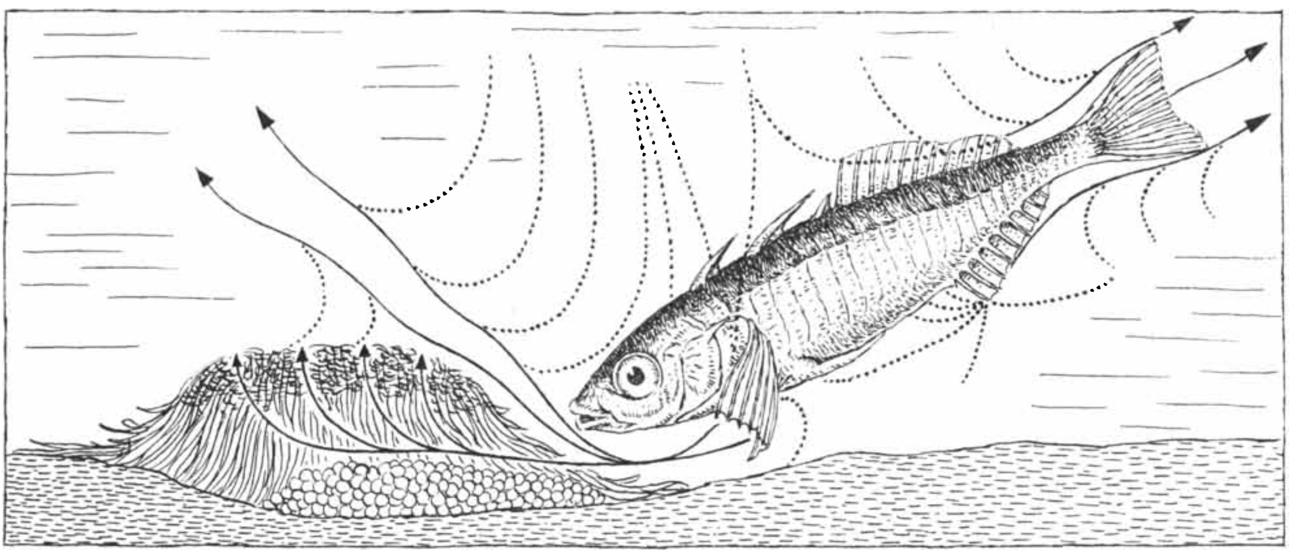
It seems likely that the rise and fall of inner drives is controlled by hormonal changes, and we are now studying the effects on these drives of castrating and giving hormones to the males. One interesting finding so far is that castration abolishes the first phases of mating, but has no effect on the parental drive. A eunuch stickleback, when given a nest of eggs, ventilates it with abandon.

IN ANY animal the innate drives themselves are only the elementary forces of behavior. It is the interaction among those drives, giving rise to conflicts, that shapes the animal's actual behavior, and we have devoted a major part of our work with the stickleback to this subject. It struck us, as it has often struck observers of other animals, that the belligerent male sticklebacks spent little time in actual fighting. Much of their hostility consists of display. The threat display of male sticklebacks is of two types. When two males meet at the border of their territories, they begin a series of attacks and retreats. Each takes the offensive in his own territory, and the duel seesaws back and forth across the border. Neither fish touches the other; the two dart back and forth as though attached by an invisible thread. This behavior demonstrates that the tendency to attack and the tendency to retreat are both aroused in each fish.

When the fight grows in vigor, how-



IN THIRD STAGE, also seen from above, the female swims into the nest. The male then prods the base of her tail and causes her to lay her eggs. When the female leaves the nest, the male enters and fertilizes the eggs.



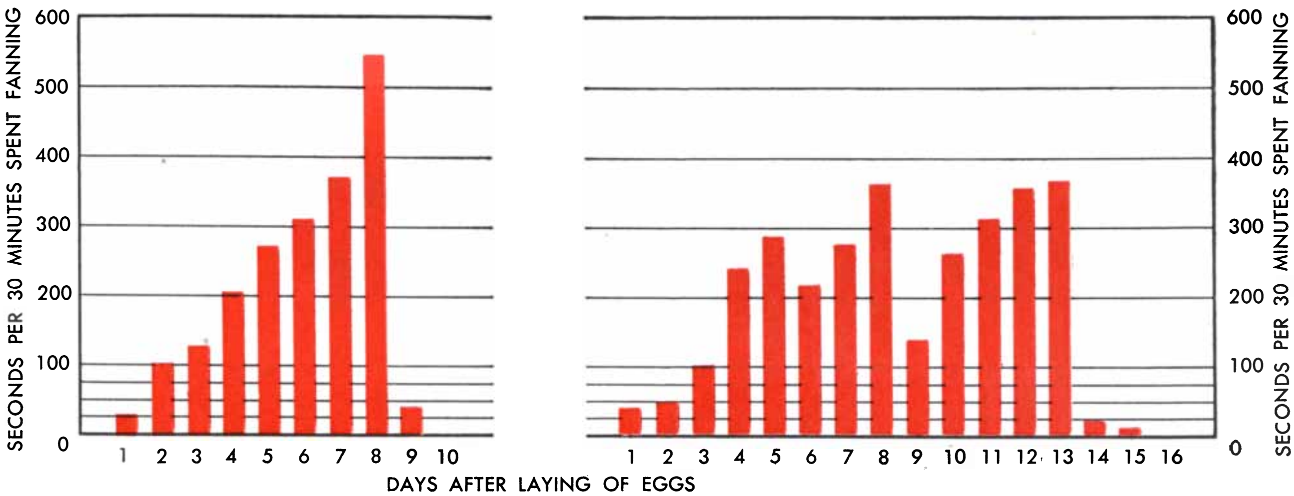
IN FOURTH STAGE the male "fans" water over the eggs to enrich their oxygen supply. The dotted lines show the movement of a colored solution placed in the tank; the solid lines, the direction of the water currents.

ever, the seesaw maneuver may suddenly change into something quite different. Each fish adopts an almost vertical head-down posture, turns its side to its opponent, raises its ventral spines and makes jerky movements with the whole body. Under crowded conditions, when territories are small and the fighting tendency is intense, both fish begin to dig into the sand, as if they were starting to build a nest! This observation at first astonished us. Digging is so irrelevant to the fighting stimulus that it seemed to overthrow all our ideas about the specific connection between sign and response. But it became less mysterious when we considered similar instances of incongruous behavior by other animals. Fighting starlings always preen themselves between bouts; in the midst of a fight roosters often peck at the ground as though feeding, and wading-birds assume a sleeping posture. Even a man, in situations of embarrassment, conflict or stress, will scratch himself behind the ear.

So it appears that the stickleback does not start digging because its nest-building drive is suddenly activated. Rather, the fish is engaging in what a psychologist would call a "displacement activity." Alternating between the urge to attack and to escape, neither of which it can carry out, it finally is driven by its tension to find an outlet in an irrelevant action.

THE THEORY of displacement activity has been tested by the following experiment. We place a red model in a male's territory and, when the fish attacks, beat it as hard as we can with its supposed antagonist. This unexpected behavior causes the fish to flee and hide in the weeds. From that shelter it glares at the intruder. Its flight impulse gradually subsides and its attack drive rises. After a few minutes the fish emerges from shelter and cautiously approaches the model. Then, just at the moment when attack and retreat are evenly balanced, it suddenly adopts the head-down posture.

A similar interaction of drives seems to motivate the male when he is courting. In the zigzag dance the movement away from the female is the purely sexual movement of leading; the movement toward her is an incipient attack. This duality can be proved by measur-



FANNING OF EGGS by the male stickleback follows a predictable pattern, as shown by the graph at the left. The fish spends more and more time fanning from the first day until the eighth. By the tenth day it has stopped fanning altogether. The graph at the right shows what happened when the eggs were removed on the sixth day and replaced with a fresh batch. The fanning pattern began anew, but the fanning time on the sixth day was still longer than that on the first. This suggested that fanning is controlled by internal as well as external factors.

ing the comparative intensity of the two drives in an individual male and relating it to his dance. Thus when the sex drive is strong (as measured by willingness to lead a standard female model) the zig component of the dance is pronounced and may shift to complete leading. When the fighting drive is strong (as measured by the number of bites aimed at a standard male model) the zag is more emphatic and may become a straightforward attack. A female evokes the double response because she provides sign stimuli for both aggression and sexuality. Every fish entering a male's territory evokes some degree of attack, and therefore even a big-bellied female must produce a hostile as well as a sexual response.

This complexity of drives continues when the fish have arrived at the nest. A close study of the movement by which the male indicates the entrance shows that it is very similar to fanning, at that moment an entirely irrelevant response. This fanning motion, we conclude, must be a displacement activity, caused by the fact that the male is not yet able to release his sex drive; he can ejaculate his sperm only after the female has laid her eggs. Even when the female has entered the nest, the male's drive is still frustrated. Before he can release it, he must stimulate her to spawn. The "quivering" motion with which he prods her is much like fanning. It, too, is a displacement activity and stops at the moment when the eggs are laid and the male can fertilize them. It is probable that the male's sex drive is frustrated not only by the absence of eggs but also by a strong conflict with the attack drive, which must be intense when a strange fish is so near the nest. This hostility is evident from the fact that the male raises his dorsal spines while exhibiting the nest to the female.

The ideas briefly outlined here seem to throw considerable light on the complicated and "irrelevant" activities typical of innate behavior in various animals. Of course these ideas have to be checked in more cases. This is now being done, particularly with fish and birds, and the results are encouraging.

I AM often asked whether it is worth while to stick to one animal species for so long a time as we have been studying the stickleback. The question has two answers. I believe that one should not confine one's work entirely to a single species. No one who does can wholly avoid thinking that his animal is The Animal, the perfect representative of the whole animal kingdom. Yet the many years of work on the stickleback, tedious as much of it has been, has been highly rewarding. Without such prolonged study we could not have gained a general understanding of its entire behavior pattern. That, in turn, is essential for an insight into a number of important problems. For instance, the aggressive component in courtship could never have been detected by a study of courtship alone, but only by the simultaneous study of fighting and courtship. Displacement activities are important for an understanding of an animal's motivation. To recognize them, one must have studied the parts of the behavior from which they are "borrowed" as well as the drives which, when blocked, use them as outlets. Furthermore, the mere observation and description of the stickleback's movements has benefited from our long study. Observation improves remarkably when the same thing is seen again and again.

Concentration on the stickleback has also been instructive to us because it meant turning away for a while from the traditional laboratory animals. A stickleback is different from a rat. Its behavior is much more purely innate and much more rigid. Because of its relative simplicity, it shows some phenomena more clearly than the behavior of any mammal can. The dependence on sign stimuli, the specificity of motivation, the interaction between two types of motivation with the resulting displacement activities are some of these phenomena.

Yet we also study other animals, because only by comparison can we find out what is of general significance and what is a special case. One result that is now beginning to emerge from the stickleback experiments is the realization that mammals are in many ways a rather exceptional group, specializing in "plastic" behavior. The simpler and more rigid behavior found in our fish seems to be the rule in most of the animal kingdom. Once one is aware of this, and aware also of the affinity of mammals to the lower vertebrates, one expects to find an innate base beneath the plastic behavior of mammals.

Thus the study of conflicting drives in so low an animal as the stickleback may throw light on human conflicts and the nature of neuroses. The part played by hostility in courtship, a phenomenon found not only in sticklebacks but in several birds, may well have a real bearing on human sex life. Even those who measure the value of a science by its immediate application to human affairs can learn some important lessons from the study of this insignificant little fish.

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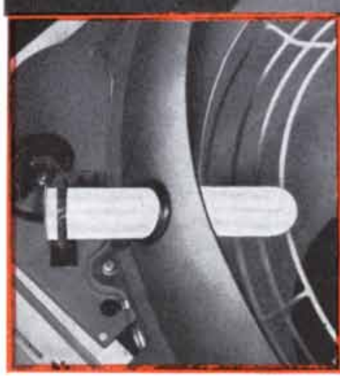

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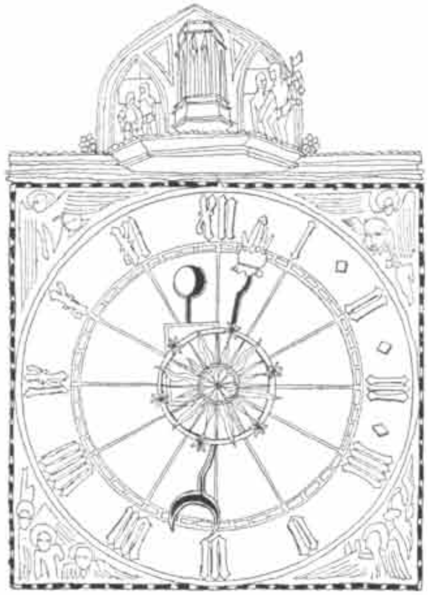


Polio Progress Report

THIS has been the year of the worst epidemic of poliomyelitis (47,665 cases) in U. S. history, but it has also been the year of the most encouraging research progress on the disease.

Large-scale gamma globulin trials in three epidemic areas for the first time afforded provable protection against polio. The tests were carried out on 55,000 children, half of whom were injected with gamma globulin (a human blood fraction rich in antibodies) and half with an inactive gelatin. Last month William McD. Hammon of the University of Pittsburgh, who supervised the program, reported on the first five weeks' results. Of the group that got gelatin, 64 children came down with paralytic polio; of the gamma globulin group, 26 were afflicted. Hammon called the difference "highly significant." The results look even better when they are broken down by weeks. In the first week following the injections the children who got gamma globulin fared little better than the control group (12 cases to 16), presumably because some of the 12 were already incubating the disease when they received their shots. Even so, the gamma globulin seemed to decrease the severity of the infection. In 30 days half of the 12 children had completely recovered, while none of the 16 controls had. In the second week only three of the GG group developed polio, compared with 23 of the control group. In the third through the fifth weeks the figures were six GG cases against 38 in the controls.

Hammon and other authorities have been at pains to point out that, encouraging as the results of the big trial are, gamma globulin will be at best a stopgap. There is not nearly enough gamma globulin to inoculate children in all epidemic areas. Moreover, the immunity conferred by gamma globulin lasts only a short time. A big question, not yet answered, is whether children who have received an injection can still acquire a mild infection when exposed to the virus and thus develop permanent immunity by manufacturing their own antibodies. Notwithstanding these limitations, the National Foundation for Infantile Paralysis says that it will use gamma globulin next year on a much larger scale.

Along with the good news about gamma globulin come two promising reports of progress toward a vaccine that will produce long-lasting immunity. Howard A. Howe, Johns Hopkins physician, has tested a dead virus vaccine on six children. He says that the subjects developed antibodies to all three types of polio viruses, although the response was poor against the Brunhilde strain, currently the most widespread of the three. None of the children reacted badly to the injections. The vaccine was prepared from virus grown in spinal cords of monkeys, and the viruses were inactivated with formalin. Howe emphasized that the work is still in its preliminary stages.

The second vaccine announcement came from Lederle Laboratories, where a weakened strain of live polio virus has for the first time been grown in chick embryos. This appears to open the possibility of large-scale, low-cost vaccine production. To produce a form which would grow in the chick embryo, Lederle scientists transplanted a Lansing virus successively through the brains of 150 suckling hamsters. By the end of the series of transplants, the strain had altered enough not only to grow in the embryo but to produce in laboratory monkeys a mild infection which gave immunity to the regular Lansing virus.

Virus Lab

LAST month the University of California opened a new $2 million biochemistry and virus laboratory. It was described by a visiting scientist at the inaugural ceremonies as "the best equipped laboratory in the world for pressing research on viruses to the deeper levels of biochemistry and genetics." The institution will be under the direction of Wendell M. Stanley, who won a Nobel prize for his work on the tobacco mosaic virus.

The Australian virologist Sir Frank M. Burnet gave the chief address at the ceremonies. He said that today it is possible to "supply protection against any infectious disease," with the major exception of poliomyelitis, "whenever the community wants it badly enough."

"It may be almost time," he added, "that we should beware of concentrating too exclusively on the perfection and extension of the laboratory approach to biology and medicine that has been so successful in the past 50 years. I cannot escape the belief that from the human angle we have obtained most of the answers that medicine can expect from it. The problems of human biology that are left when we eliminate infectious disease, malnutrition and simple physical disability may need a basically different approach. Somehow the discipline of the experimental sciences will need to be applied to social problems more difficult than those involved in conventional public health activities. Human genetics, both at individual and population levels, and those human interactions of aggression, subordination, frustration and the like—human 'peck orders' is a phrase I like—these seem to be the two great fields of scientific enquiry that will need to grow alongside experimental biology if the scientific approach is to be successful in alleviating human ills in the second half of the century as it has been since 1900."

Nobel Prizes

THE 1952 Nobel prizes in science were awarded to three U. S. and two British scientists. Selman A. Waksman of Rutgers University won the medicine award for his contribution to the treatment of tuberculosis through the discovery of streptomycin. Felix Bloch of Stanford University and Edward M. Purcell of Harvard University shared the physics prize for their work in microwave analysis of atomic nuclei. The prize in chemistry was divided between A. J. P. Martin of the National Institute for Medical Research in London and R. L. M. Synge of Aberdeen University in recognition of their development of partition chromatography. Each full prize this year is $33,000.

Waksman has been studying soil microbiology since 1915. It was not until 1939, when his former pupil, René Dubos, announced the discovery of tyrothricin, that Waksman turned his attention to the medicinal possibilities of soil organisms. Then he and his group screened some 10,000 cultures, from soil samples gathered all over the world, and eventually found his powerful antibiotic in *Streptomyces griseus*, an organism he had isolated in 1915.

The discovery that won the physics award was developed by Bloch and Purcell independently at about the same time. Their technique has been described as "an almost incredibly refined procedure for resonating directly with the nuclei, making them literally dance in rhythm with a radio wave." By measuring the exact frequency of this dance, physicists can determine the magnetic properties of the spinning nuclei. The methods developed by the two prize-winners are slightly different. Both use a strong, steady magnetic field to align the nuclear magnets of the material under study. In Purcell's method, known as nuclear resonance, a variable high-frequency radio wave is applied. At a certain frequency the nuclei flip over, absorbing energy from the radio wave. Purcell was able to measure the resonant frequency with an accuracy of one part in 30,000. Bloch's approach, called nuclear induction, applies radio energy in such a way as to make the protons in the nucleus send out radio waves of their own. The interaction of the magnetic field and the applied radio wave on the proton magnets makes them wobble, causing them to generate their own waves at right angles to the applied wave.

Martin's and Synge's contribution to chemistry was to extend the exquisitely sensitive procedure of chromatographic analysis to compounds soluble in water. Previous workers had developed the method of separating mixed substances by dissolving them in fat solvents and allowing them to flow slowly through a column of solid adsorbent. Different molecules flow at different rates, and so are separated into distinct layers. In Martin and Synge's partition chromatography technique the solid adsorbent is replaced by water, held in a porous solid such as starch. The mixed material, dissolved in a solvent which does not mix with water, percolates through the column, and the molecules pass back and forth between that solvent and the water. Again they do this at different rates and so are separated. This technique made it possible to isolate a number of compounds important in biochemistry, notably the carbohydrates and the amino acids. Martin and other workers later used the method to develop paper chromatography, in which the separations are carried out on sheets of adsorbent paper, rather than in packed glass columns.

The Nobel winners in chemistry and physics this year were all of the younger generation that has developed since World War II. Martin is 42, Synge 38, Bloch 47 and Purcell 40.

Amateur Astronomer

LITEL Lowys my sone, I apercyve wel by certeyne evydences thyn abilite to lerne sciences touching nombres and proporciouns. . . . Therefore have I yeven the a suffisant Astrolabie as for our orizonte compowned after the latitude of Oxenforde.

So wrote one of Albert G. Ingalls' predecessors in amateur astronomy, Geoffrey Chaucer, in his *Treatise on the Astrolabe*. Recently Derek J. Price of Cambridge University reported new evidence of Chaucer's interest and competence in astronomy. A handwritten manuscript entitled *Equatorie of the Planetis*, found in the Peterhouse library at Cambridge, has been identified as almost surely written by Chaucer. In it he describes a circular wooden model about six feet in diameter for determining the positions of the planets at any time, and his manuscript gives extensive tables for calculating these positions.

Chaucer had an excellent grasp of the Ptolemaic system for a layman. Price calls his *Treatise on the Astrolabe* "still today the best work in the English language on this extremely important medieval instrument." The astrolabe was a device for calculating the positions of the fixed stars.

Space Travel

TO people who are laying plans for taking off to the moon within the next 10 or 15 years a rocket expert recently offered a discouraging word. Milton W. Rosen, director of the Viking Rocket Project, took issue with the prevailing optimism among astronauts at a symposium on space travel in the American Museum of Natural History. Said he: "I can hardly conceive of anything that would do more harm to this country's defense efforts, and to the cause of space flight itself, than for the U. S. to undertake any one of the fantastic projects for a space ship that have been proposed in the last few years."

Rosen argued that engineers have gone about as far as they can with the present fund of basic scientific knowledge. Present knowledge, he said, might make possible a manned flight to a height of 50 miles and return, but to go higher scientists will have to learn much more about cosmic and solar radiation, rocket-motor combustion theory and materials. He said that progress in these fields has been slow. He recommended that an advisory group be set up, possibly under the National Science Foundation, "to determine what we are doing and what we could do to make further progress."

Quicker Freeze

THE trick in preserving quality and flavor in frozen foods is to freeze them quickly. The shorter the freezing period, the smaller the crystals that are formed and the less the damage to food cells. In Denmark engineers have recently announced a new superfast freezing process.

Most commercial freezing is done with

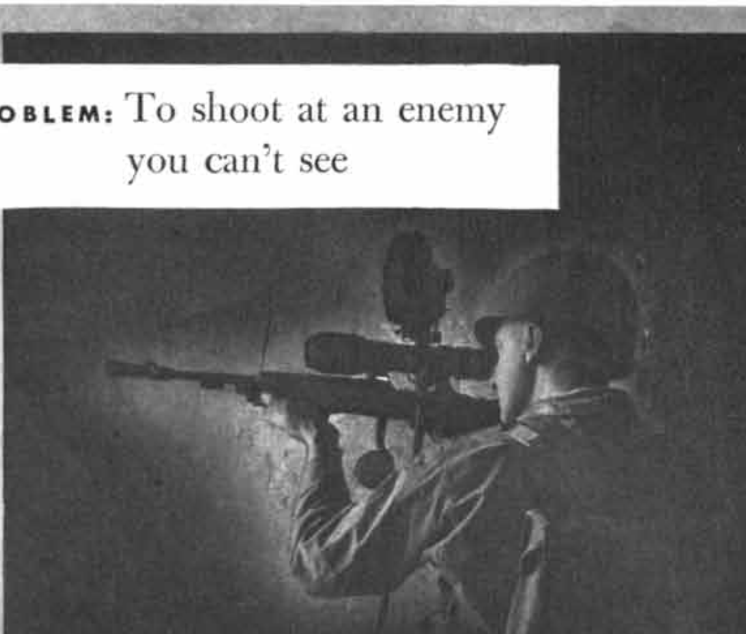
PROBLEM: When is water safe to drink?

ANSWER: Are there harmful bacteria in the water you drink? Local health authorities have to know. Most cities give their water supply daily microscope tests. A microscope specially designed for the job by AO helps determine the exact nature and quantity of the bacteria or other organisms in a sample of drinking water . . . assists in keeping impurities under control.

PROBLEM: Why some bright children fail in school

ANSWER: Most youngsters who fail are poor readers. To enable doctors and educators to study eye movements and how they affect reading skills, AO scientists developed the *Ophthalmograph.* It provides a permanent record of eye movements so rapid they can't ordinarily be measured. Such information is used to diagnose and treat people who need visual training and reading instruction.

PROBLEM: To shoot at an enemy you can't see



ANSWER: The *Infrared Sniperscope* sees in the dark by throwing invisible rays on the target, making it visible in a special telescope. American Optical has contracts for production of the Sniperscope. AO designs and manufactures many specialized instruments. Write us about your development problems. Address American Optical Company, 37 Vision Park, Southbridge, Mass.

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a blast of cold air. But air is an inefficient heat transfer medium. The Danish process, as reported in *Industrial and Engineering Chemistry,* uses a freezing bath of water, glycerol and ethyl alcohol at a temperature of 20 degrees below zero Fahrenheit. In this bath a 12-pound cut of beef can be cooled from 32 degrees to 23 degrees (the critical temperature range in which the freezing takes place) in two hours instead of the usual four. When the food has reached 23 degrees, it is removed from the bath and placed in an air blast which further cools the food to 16 degrees below zero—the best temperature for long storage.

In addition to freezing the interior of the food more quickly, the method freezes the surface almost instantaneously, preventing any transfer of odor or flavor to the solution. Mixed batches of herring, strawberries, cauliflower, oranges and chicken have been successfully treated together.

The Danish process is said to be cheaper, to reduce microorganism activity, to avoid shrinkage, to eliminate the need for blanching or sugaring fruits, and to make possible the freezing of whole grapefruit, oranges, tomatoes, melons and grapes.

Under U. S. law ethyl alcohol may not be used in contact with foods during processing. The Danes claim that their method freezes food surfaces so quickly that no alcohol is absorbed by the food.

The Naked Spindle

THE dramatic events that take place in a living cell when it divides have always fascinated biologists. Within the seemingly formless material of the cell nucleus threadlike chromosomes suddenly appear. Meanwhile in the surrounding cytoplasm fibers begin to grow from two tiny centers, and they soon unite to form one spindle-shaped body. Now the skin of the nucleus melts away and the chromosomes move into the spindle, there to pair off at the opposite ends. Then the whole cell constricts in the middle until it splits in two—two identical cells where previously there was one.

Watching this process of mitosis under their microscopes, biologists have often wondered whether they were seeing a true picture of the physical events in cell division or merely an artifact, perhaps caused by chemical reactions of the cell material to the stain used to make the cell visible. Proof that the behavior of the chromosomes, the spindle and the rest of the apparatus is not a chemical or optical illusion has now been put into concrete form by two zoologists. Daniel Mazia of the University of California and Katsuma Dan of Tokyo Metropolitan University have succeeded in isolating the mitotic apparatus naked and intact.

Mazia and Dan described their feat in

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first **IN WIRE-WOUND RHEOSTATS AND RESISTORS** the *Proceedings of the National Academy of Sciences.* They fertilize sea-urchin eggs and, when the eggs have reached the desired stage of division, fix the preparation in alcohol. They can then separate out the mitotic apparatus, either by forcing the cells through a fine hypodermic needle, which squeezes off the cytoplasm, or by dissolving away the cytoplasm with hydrogen peroxide and a detergent. The naked mitotic bodies under the microscope have the same appearance as in the cell. Chemical analysis shows they are composed largely of protein. About two per cent of the total protein material of the egg goes into their formation.

British Bomb

PRIME MINISTER Winston Churchill last month announced a few details of the first British atomic bomb test, made in the Monte Bello Islands off the Australian coast in October. The bomb was exploded inside a small frigate in a harbor. The ship, said Churchill, was completely vaporized, except for some red hot fragments that scattered over one of the islands. Measurements of the radiation energy as the blast broke out of the hull showed that the temperature at the hull was almost one million degrees.

Observers from the mainland reported that the cloud thrown up by the bomb, unlike the mushroom clouds characteristic of U. S. bombs, had the shape of a ragged "Z." Churchill said that "thousands of tons of water and of mud and rock from the sea bottom were thrown many thousands of feet into the air and a tidal wave was caused." He added that damage effects were tested in specimen structures erected at various distances from the explosion.

The bomb project cost the British well over $280 million. It was directed by W. G. Penney, a physicist who had worked at Los Alamos during World War II. Churchill said he hoped the successful test would lead to "a much closer American interchange of information" with Britain about atomic energy.

European Nuclear Research

TEN governments will cooperate in building and operating a $25 million European laboratory for nuclear research, to be located in Geneva. The participating nations are Denmark, France, the Netherlands, Italy, West Germany, Sweden, Belgium, Yugoslavia, Norway and Switzerland.

The European laboratory may be the first to build the super-powerful synchrotron based on the strong-focusing principle worked out at the Brookhaven National Laboratory ("Science and the Citizen," SCIENTIFIC AMERICAN, November). Its sponsors had sent Odd

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Germanium diodes, diffused junction rectifiers and transistors are manufactured at the Clyde plant and the Model PM1 Induction Heater plays an important role in a sub-assembly operation on the whisker diode line. A very small pellet of germanium metal is soldered to the end of a nickel pin and the Induction Heater is used to elevate the temperature to the desired value.

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Weight: 150 pounds

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The entire unit is rigidly assembled and mounted to prevent arc-over and failure of components. It easily meets latest F.C.C. requirements on radiation.

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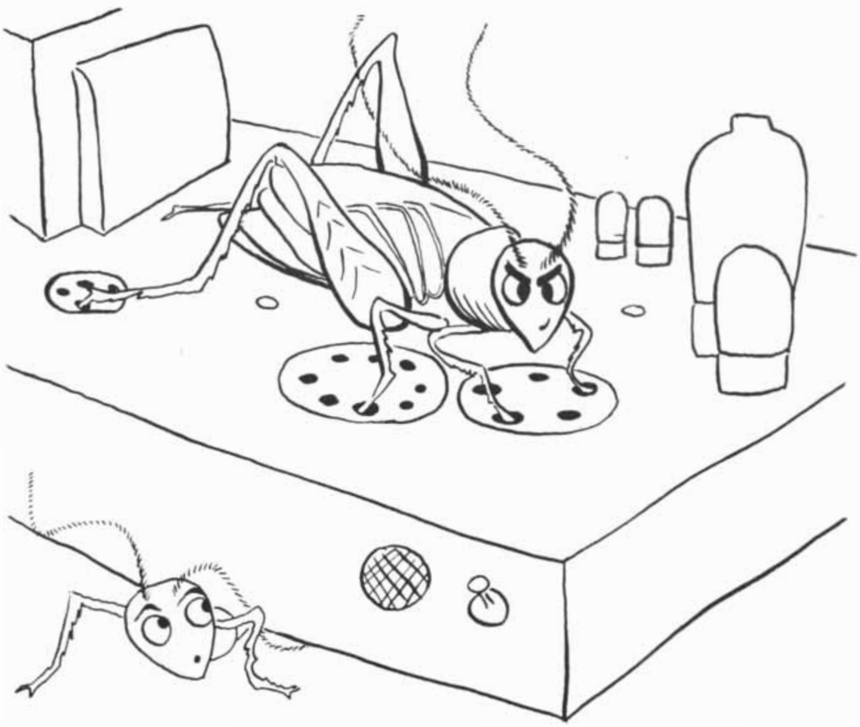

Dahl, Norwegian physicist, to Brookhaven to see the cosmotron. While there he learned of the strong-focusing idea and returned home to propose building a 30-billion-volt machine such as the Brookhaven workers had suggested.

British Isotopes

GREAT BRITAIN now leads the U. S. in the export of radioactive isotopes. The British Ministry of Supply recently announced that in the past year 3,053 shipments of isotopes were made to 37 different countries. The isotopes are produced at the Atomic Research Establishment at Harwell.

The English journal *The Engineer* reports that the British Overseas Airways Corporation has developed a novel and economical method for transporting radioactive material. B.O.A.C. planes carry it in their wing tips, which dispenses with the need for heavy lead shielding and reduces shipping costs by more than 60 per cent.

Military Science

THE U. S. Government's pressure upon universities to do military research is converting many graduate schools into "commercial development establishments," according to George B. Kistiakowsky, professor of chemistry at Harvard University. Kistiakowsky, onetime chief of the explosives division of the Los Alamos Scientific Laboratory, objected vigorously to the effects of the research contracts at a recent forum at Mount Holyoke College.

He acknowledged that many government contracts successfully combine the needs of the military with the requirements for good education. But he objected that too often universities accept contracts for their prestige and for their financial return, with no thought to the possible ill effects they may have on the students who must fulfill them. "I see ourselves threatened," said Kistiakowsky, "with a generation of scientific workers who know how to carry out instructions and to follow in the footsteps of others, but who have not learned how to discover a rewarding research problem, how to plan the attack on it and how to solve it."

He suggested that the military establishments employ university personnel to help them draw up projects.

Commissioner Resigns

T. KEITH GLENNAN, member of the Atomic Energy Commission since August, 1950, resigned last month. He wrote President Truman that commitments to his college, the Case Institute of Technology, and family responsibilities compelled his immediate return to private life.

STEEL WOOL bursts into flame under a jet of fluorine gas in an experiment at The Whitemarsh Research Laboratory of The Pennsylvania Salt Manufacturing Company.

When Metal Bursts into Flame

Imagine, if you can, an element so fierce it burns up steel. One that claws its way through fire-brick . . . makes water burn like alcohol . . . destroys almost everything it touches.

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If it's corrosion, it can't be any tougher than that caused by fluorine . . . and the solution may be found in Inco Nickel or one of the Inco Nickel Alloys.

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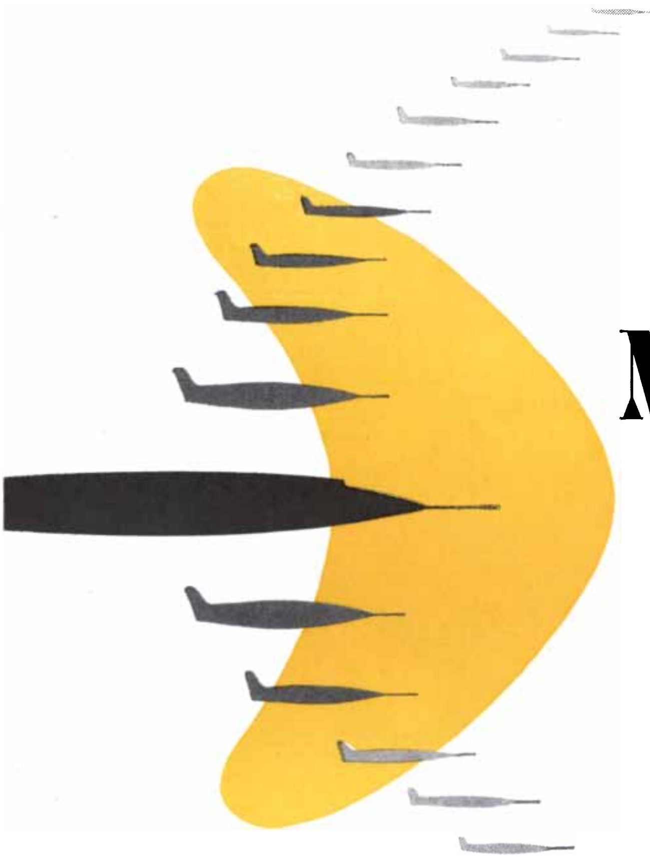

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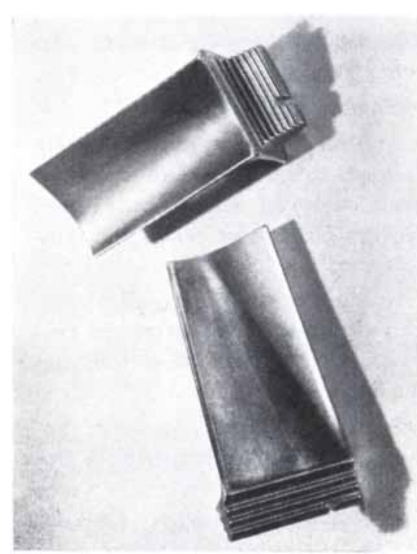

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THE NATURE OF SOLIDS

The theory that explains their various properties is a comparatively recent development of physics. From it practical benefits already begin to flow

by Gregory H. Wannier

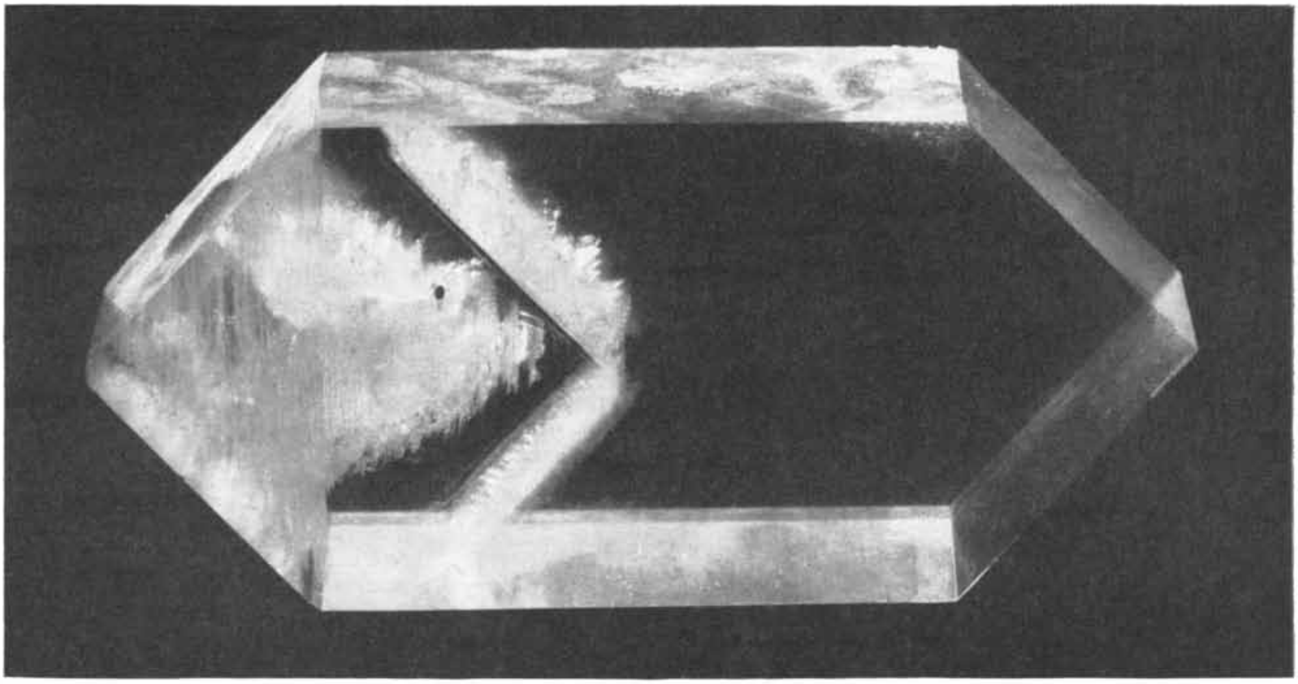
EVERYONE develops in the course of his life a general notion of what a solid body is: that which supports when sat on, which hurts when kicked, which kills when shot. We have also known for a long time certain laws of the behavior of solid bodies: the laws of free fall, of refraction, of elasticity and so on. Yet none of those laws really describes the nature of the solid state. Long after the behavior of gases had been formulated and explained in terms of molecular action, the essential character of the solid state remained a secret. No suggestion of an answer was forthcoming to the question how the same molecules could behave so differently in a solid and in a gas. In fact, the question was not even clearly asked for a long time, and an unasked question is especially difficult to answer.

The physics of the solid state is a new science, developed only within the present century. It is often the unusual and startling aspects of a subject that wake it from its slumber. Two such aspects can be singled out as having opened up the physics of the solid state at the turn of the century: the structure of crystals and the conduction of electricity by metals.

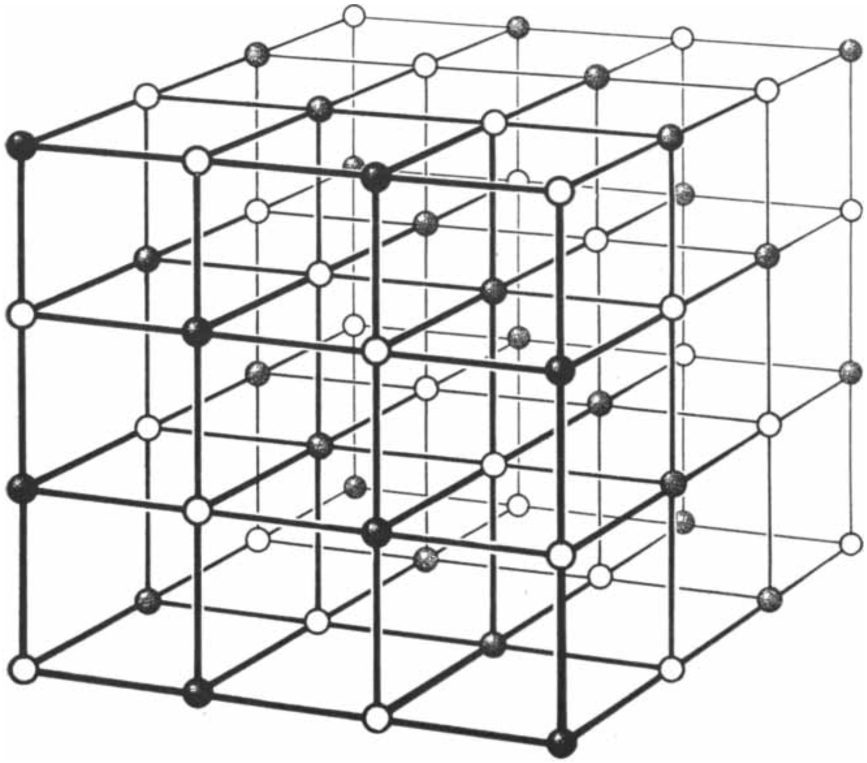
Crystals have never suffered from the lack of glamour which so long delayed progress in the physics of the solid state. The travelogues of the ancients are liberally sprinkled with mentions of wondrous gems. The classification of crystals was one of the chief occupations of Arab scientists. To these early observers, crystals seemed to be exceptional forms of solids. Nineteenth century research disclosed, however, that this view was not correct. It is only the *well developed* crystals that are exceptional. A very large number of solids which do not appear to be crystalline at first sight are seen to be composed of tiny crystals when examined under the microscope. The list includes all rocks and all metals; only a small group of recalcitrant solids such as glass fail to show any trace of crystallinity.

Crystal Structure

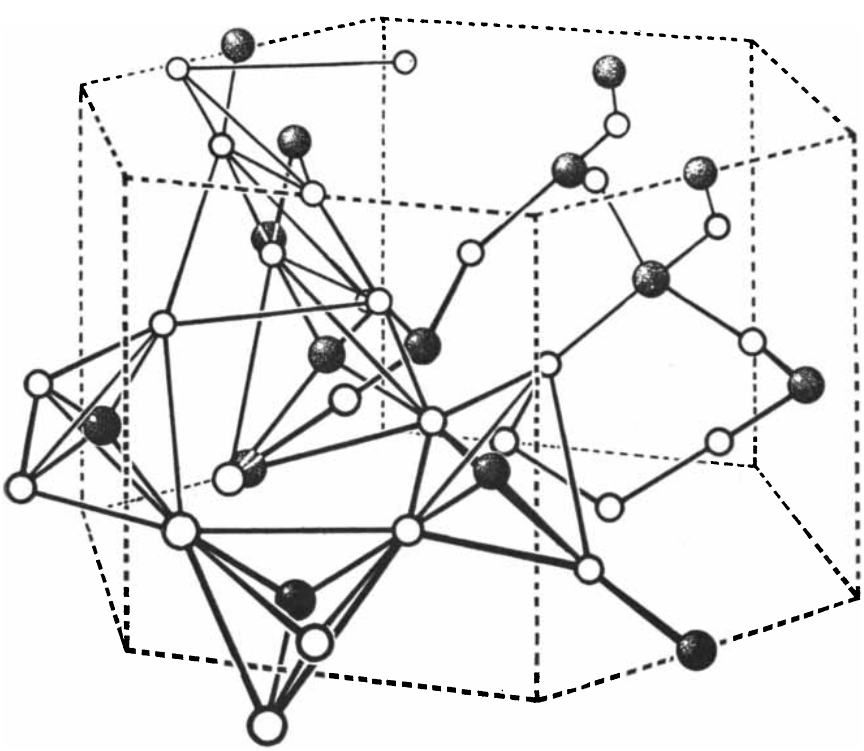
Crystals are homogeneous solids bounded by plane faces. Many of them are strikingly symmetrical in shape; for



CRYSTAL owes its characteristic shape to the regular geometry of its atomic structure. This crystal is ethylene diamine tartrate (EDT), which is grown in solution and cut into sections to control electrical frequencies.



COMMON SALT or sodium chloride crystal is made up of cubic units. The bonds between sodium (*black*) and chlorine (*white*) are marked by lines.



QUARTZ or silicon dioxide has a basic hexagonal structure determined by the angles of the bonds between silicon (*black*) and oxygen (*white*).

example, the little cubes formed by rock salt and the hexagonal prisms of quartz. Even in some of those that are not fully symmetrical, the asymmetry is often due simply to the fact that certain planes have been shifted parallel to themselves. If the angles between the planes are taken as the basic indication of structure, the same structure always goes with the same chemical species. For this reason crystals acquired great value to the chemist as a means of identifying and preparing his chemical compounds. He had only to permit the substance to crystallize out of a solution or a melt; it then corresponded (with some exceptions) to a simple chemical formula. Thus there was added to the geometric simplicity of crystals their simple chemical behavior.

It was inconceivable that this combination of properties was not due to a symmetry in the internal constitution. A regular arrangement of molecules was postulated, and the consequences of that postulate were worked out by mathematicians with the tool of group theory. They proved in particular that any crystalline symmetry can be obtained by reproducing the same unit over and over through identical parallel displacements, like so many houses in a modern housing development. This unit, called the unit cell, is not necessarily identical with the individual molecule; indeed, we know today many cases in which there are several molecules per unit cell. The parallel displacements form a lattice, the so-called Bravais lattice. The final triumph of this viewpoint was achieved by the proof that an arrangement based on molecular symmetry could never exhibit the five-sided symmetry which is so common in living nature (*see drawings on page 47*).

When it became possible to measure the positions of atoms in crystals with X-rays, these crystallographic theories became one of the foundations of the new physics of the solid state. The discovery of this technique was made in 1912 by Max von Laue of the University of Munich and his associates Walter Friedrich and C. M. Paul Knipping. The experiment, one of the most important of all time, arose in the following way. Von Laue, a member of the laboratory of Wilhelm Röntgen, the discoverer of X-rays, was inclined to consider these rays as electromagnetic waves; that is, of the same nature as radio waves or visible light, but of much shorter wavelength. To prove that they were waves he had to construct or find gratings much finer than any grating ever made by man. At this point he happened to become acquainted with studies then being made of crystals, and he perceived that here was a grating made by nature which should serve his purpose. At his suggestion Friedrich and Knipping directed a beam of X-rays at a crystal, and looked for reflections from the regular crystal planes which existed in the interior. After some unsuccessful trials these reflections were found.

Within a few years the technique of diffracting X-rays by means of crystals was taken up by others, notably W. H. and W. L. Bragg, father and son, in England. Today it has become a standard tool for analyzing crystal structure, while its original purpose—determination of the wavelength of X-rays—has receded into the background. The simplest example, and the first to be analyzed with this tool, is the sodium chloride crystal, NaCl (*see drawing on the opposite page*). The partners Na and Cl occupy the corners of a cubic lattice; they alternate in this position, like the black and white squares of a checkerboard. Each Na is surrounded impartially by six Cl's at equal distance, and *vice versa*.

Thus crystallography provides a geometric analysis of the solid state which is unusual in its beauty and perfection. But it is not yet physics. Johann Kepler's laws of planetary motion, which had a similar beauty, were not physics but astronomy; Newton transformed them into physics by finding the law of force to which the planets were subject. In the same way physicists asked what forces made the atoms in crystals arrange themselves as they did, and what dynamic phenomena took place in crystals. They learned that the forces responsible for the formation of atoms, molecules and crystals are electrical, which placed solids and molecules on a similar footing.

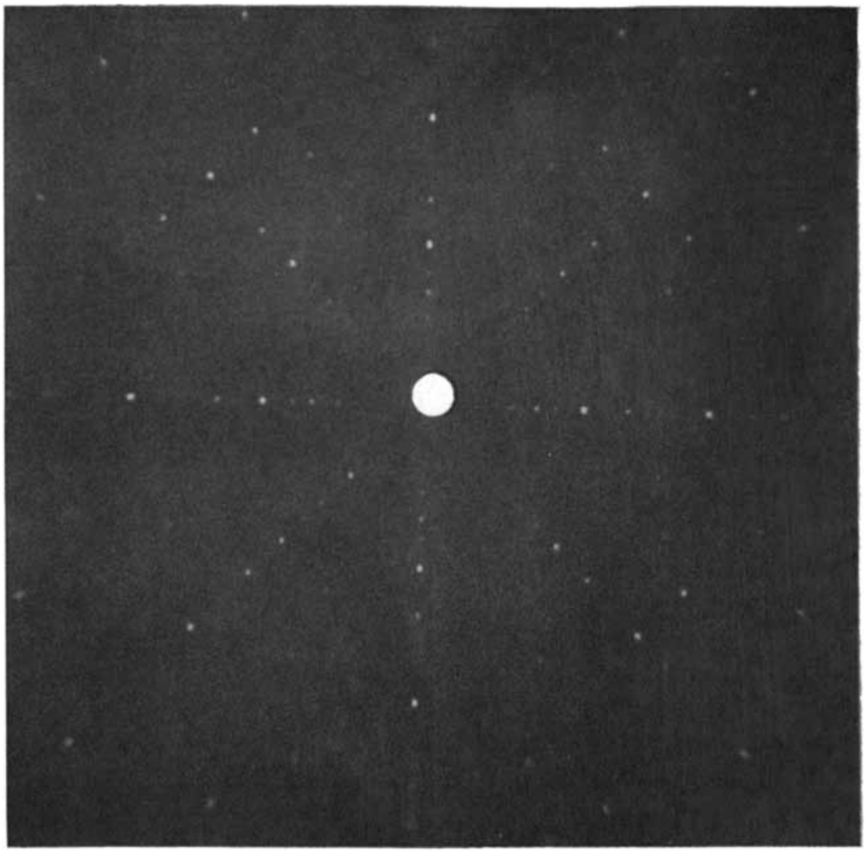
The Bond

It is therefore appropriate to examine the chemical binding forces in molecules as a preliminary to the more complicated case of solids. The basic unit of these forces is the negatively charged electron. Even before the discovery of the electron by the Cambridge physicist J. J. Thomson in 1895 the existence of units of electrical charge had been detected in solutions. When a salt such as sodium chloride is dissolved in water, the molecule dissociates into sodium atoms, charged positive, and chlorine atoms, charged negative. These charged carriers, called ions, are identified by the passage of an electric current, in which a transport of charge is linked in a fixed way with deposition of matter—atoms of sodium on one electrode and atoms of chlorine on the other. Thomson's discovery that the charge of the electron was identical with the known unit of charge of ions suggested immediately that electrons were constituents of the atom and that ions were characterized by an excess or a defect of such particles.

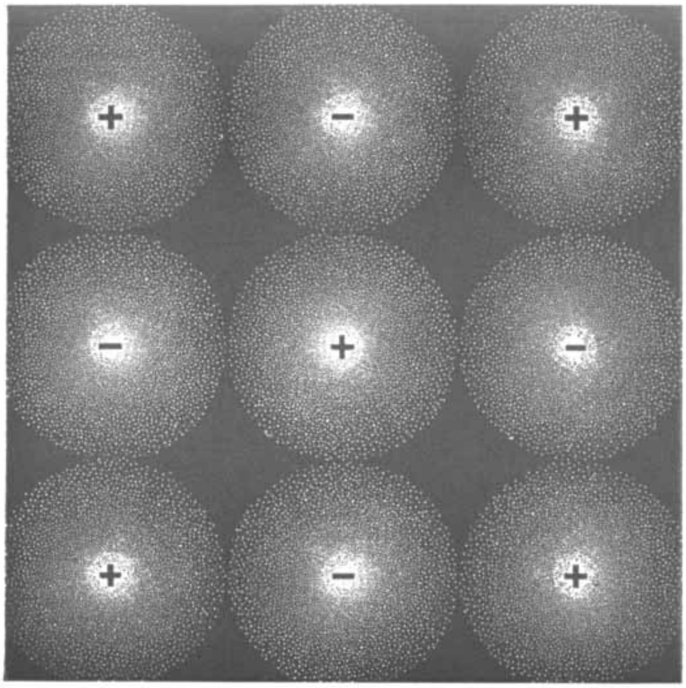
At first the electrons in the atom were thought of as negative raisins in a positively-charged cake; then it was shown that the positive charge, far from being a cake, is concentrated in an extremely small space within the atom where it forms the atomic nucleus, about which the electrons cruise very much like the planets around the sun. Next it was seen that the charge of this nucleus determines the chemical element. Thus the atom of copper consists of a nucleus bearing 29 positive charges surrounded by 29 negative electrons; from it an ion with two extra units of positive charge (Cu^{++}) is derived by the surrender of two electrons. The manner in which these electrons are bound to the nucleus was elucidated only after considerable difficulty. It was learned that the electrons were restricted to certain definite orbits, representing energy states, around the nucleus. A modification of mechanics, called quantum or wave mechanics, had to be evolved to pick out the possible orbits; between these possible states the electrons can make transitions, emitting or absorbing the energy difference in the form of light.

The picture was reasonably well completed by the discovery in 1927 that the electron spins on its own axis, much as the earth does, and that only two states of rotation are possible. With this discovery, it became possible to formulate the so-called Pauli exclusion principle, which states that two electrons cannot be in the same quantum state including spin. The Pauli principle gives the electrons around the atom a shell structure, and so explains valency.

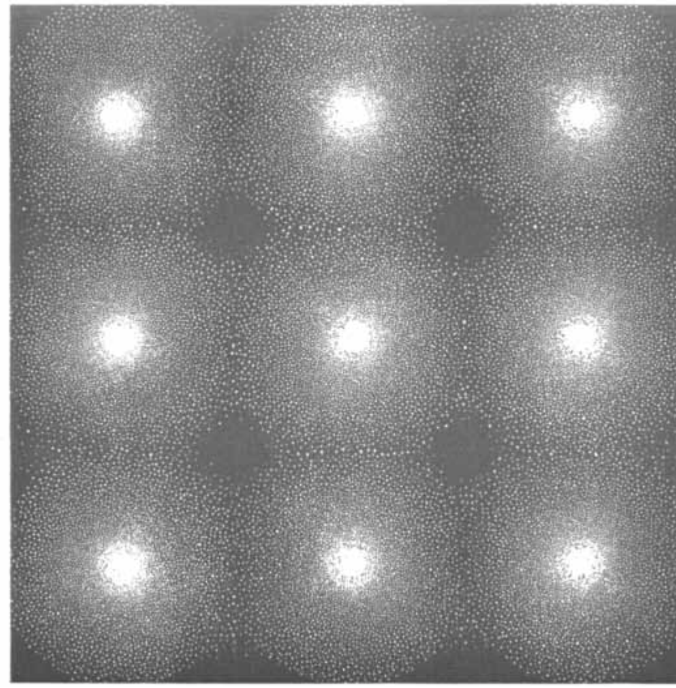
Thus the lightest atom, hydrogen, which consists of a nucleus bearing one positive charge and an electron, has the valency 1, corresponding to the fact that it can surrender its electron to an atom desiring one, as it does in hydrochloric acid (HCl). The next atom in order of weight, helium, has two charges and two electrons. This arrangement is so stable that the electrons do not usually leave the atom and helium does not form chemical compounds. The next atom, lithium, has three electrons, only two of which can enter the stable helium shell, while the third, called the valence electron, is easily detached. Consequently lithium has valence 1 and forms salts such as lithium chloride, in which lithium bears a positive charge; a solution of this salt in water will conduct electric current, with lithium coming out at the negative pole. Beryllium, the next element, has two valencies, and so on up the scale of elements. The chemically inert gas argon, with 10 electrons, fills the second shell. The element immediately preceding argon, fluorine, lacks one electron in the second shell and is an extremely reactive substance with one valence. The valence is of the electronegative type; that is, fluorine tends to grab an electron to complete its second shell. In consequence a salt such as lithium fluoride, in which the lithium



X-RAY DIFFRACTION PATTERN of a barium titanate crystal has a regular array of spots. The hole in the center is for mounting the negative.



IONIC CRYSTAL is composed of atoms held together by opposite electric charge. The shading of each atom represents the density of the electron cloud about its nucleus.



COVALENT CRYSTAL is composed of atoms that share their outer electrons. The outer part of each electron cloud joins that of its neighbor.

atom passes one electron to the fluorine atom, is very stable, because both atoms are now surrounded by complete electron shells. After argon comes sodium, with 11 electrons, one of which is detached easily; this means that it will act very much like lithium. Thus the elements fall into groups of similar behavior according to the structure of the outermost shell. The group of atoms having just one electron outside a closed shell is called the alkali metals. This group occupies a key position in the theory of the solid state, as will be seen.

Crystal Bonds

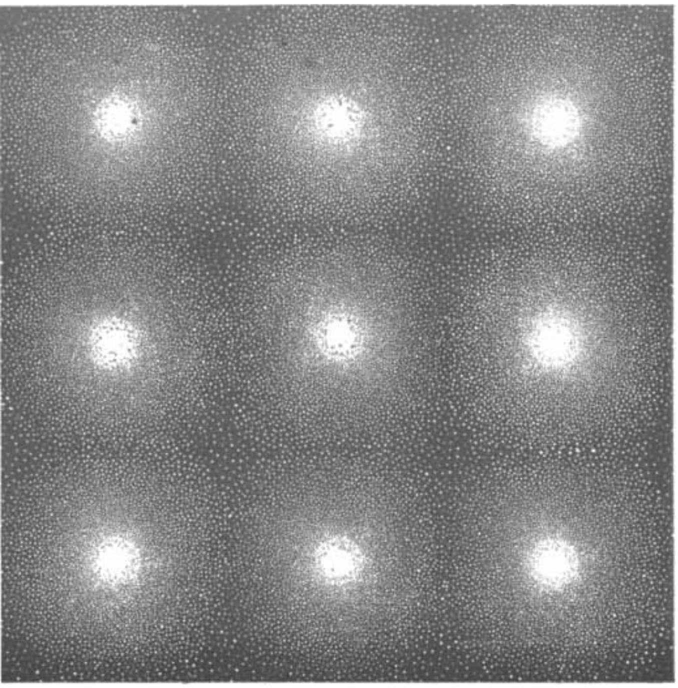
Now let us return to the structure of crystals. The simple lattice of the sodium chloride crystal is composed of ions. Ionic crystals had revealed something of their electrical character as early as the 18th century. Jewelers, testing the durability of the colorful gem tourmaline by putting it in the fire, noticed that foreign particles collected on it, and they named it "the stone which attracts ashes." Careful study showed that the gem became electrified when it was heated, always in the same crystallographic direction, positive charges appearing on one crystal face and negative charges on its opposite. More than a century later French scientists followed up this discovery of a "pyroelectric" effect with demonstration of the "piezoelectric" effect—the electric polarization of certain crystals under pressure. These polarizations result from shifts in the equilibrium positions of the ions; the ions return to their original positions when the heat or the squeeze is removed. The shift of positive ions is different from that of negative ones. Today piezoelectricity is sufficiently well understood to have made possible the design of artificial crystals which can replace natural quartz in some applications ["Crystals and Electricity," by Walter G. Cady; SCIENTIFIC AMERICAN, December, 1949].

The ionic crystals, and sodium chloride in particular, were not only the first solids whose structure was analyzed, but also the first chemical compounds whose chemical binding energy was accounted for by physical principles. This feat was accomplished by the German scientists Fritz Haber and Max Born. Haber suggested that the chemical binding of sodium and chlorine in the rock salt crystal was accomplished simply by the electric attraction of Na^+ and Cl^-. If this hypothesis was true, the chemical binding energy could be computed in electrical terms, and Born was able to do so. His calculation was the first computation of a chemical quantity from physical premises. The importance of this step cannot be exaggerated. One can infer from it that very probably all chemical binding is electrical in the last analysis, and that it should be possible to implement this view by direct computation.

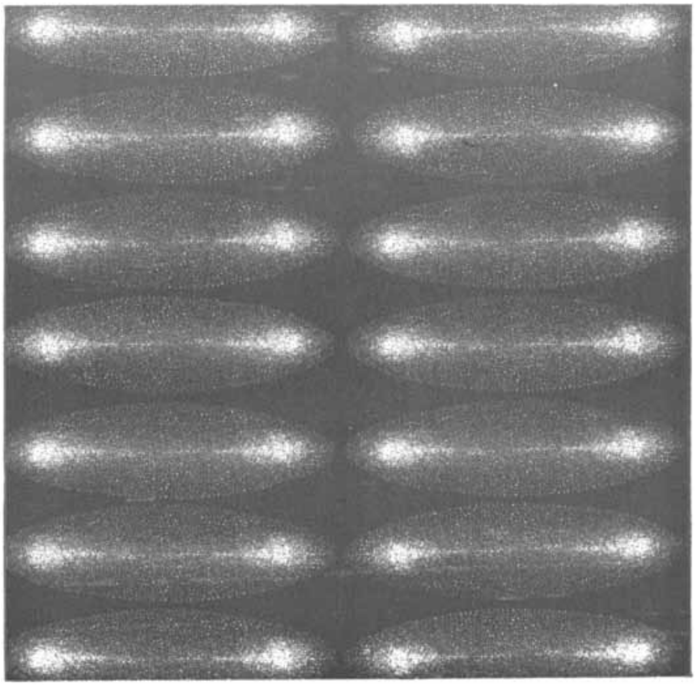
To explain how solids hang together, however, one missing link remains to be forged. The ionic concept does not account for the binding of atoms in all chemical compounds. In the molecules of hydrogen (H_2), oxygen (O_2) or chlorine (Cl_2), for example, neither of the two atoms which compose the molecule carries an effective charge. Similarly in many metallic crystals all the atoms are known to be in the same condition, and in consequence, we cannot possibly assume half of them to have positive charge and half negative. The chemical bond in such cases is called covalent. It is one of the successes of quantum mechanics that it can explain the covalent bond; because of its importance for the theory of the solid state as well as for chemistry we must examine that bond in some detail.

The Covalent Bond

Quantum mechanics, sometimes called wave mechanics, represents the final formulation of a schizophrenic viewpoint which has evolved in 20th century physics. Earlier scientists heatedly debated whether light was made up of particles or waves. This conflict finally was resolved by the assertion that it is both. There is a discrete unit of light called a quantum, but if we try to locate this particle, we must apply wave theory. The height of the wave at any point gives the probability of finding the light quantum at that spot. Wave mechanics is concerned with the second stage of this reasoning. If light waves are also particles, then particles are also waves. The wave pattern associated with a particle gives the probability of finding it at a given spot: on the wave crests the probability is high, in the troughs it is low. The wavelength of this "probability wave" is obtained from the formula devised by the French physicist Louis de Broglie; the wavelength equals Planck's constant divided by the mass



METALLIC CRYSTAL is composed of atoms whose outer electrons are so loosely held that they are free to move through the crystal lattice.



MOLECULAR CRYSTAL is made up of molecules. These are held together by weak forces due to the attraction of nuclei in one molecule for the electrons of another.

times the speed of the particle. It follows from this formula that a particle cannot be located with certainty within a space much smaller than one de Broglie wavelength. Therefore you cannot confine the particle without doing work, because in order to do so you have to reduce its wavelength. This reduction can be accomplished in de Broglie's formula in only one way: by increasing the speed of the particle. An increase in speed means an increase in energy, which has to be supplied from somewhere.

For electrons this feature of quantum mechanics is particularly important, because the mass of an electron is far less than the mass of an atom and hence the wavelength tends to be larger. The compression of an electron into a space of atomic dimensions therefore requires significant amounts of energy. If an electron is given a chance to spread itself over several atoms it will do so, and, between two possible states of matter, the one in which the electron has that chance will be the more stable, other things being equal. The question remains: What limits this process? Why do not all electrons spread out their waves indefinitely? The answer is Pauli's exclusion principle. Each possible wave pattern is a quantum state in the sense described for atoms, and according to the exclusion principle only two electrons (for the two directions of spin) can spread themselves out in the lowest energy state, or wave pattern. The third and fourth electron must go into the next higher state, and so on. The tendency to form covalent bonds can be described as the tendency of the electrons to extend their wave patterns, and thus to reduce their energy of motion, as far as this is compatible with the Pauli exclusion principle.

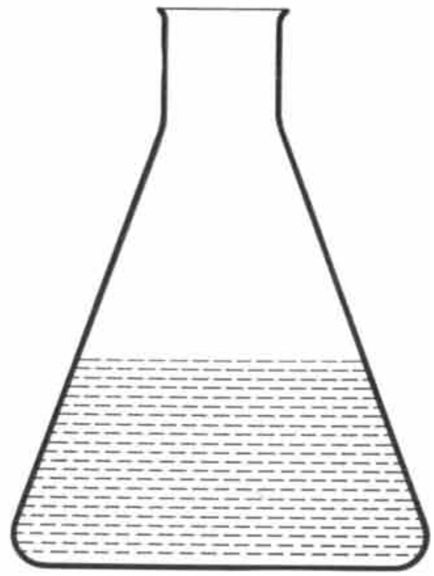
Take as an example the simplest molecule, H_2, formed by two atoms of hydrogen. The system contains only four constituents: two positively charged nuclei and two electrons. When the two atoms are far removed from each other, the electric forces confine each electron to its own nucleus. If the two atoms are brought closer, the wave corresponding to each electron can be spread over the two nuclei, lowering their energy. The Pauli principle can be satisfied by giving the electrons opposite spin. In consequence the energy of the system as a whole is lowered, and the two atoms cannot be separated again without furnishing a certain amount of energy; this is the chemical binding energy of the molecule H_2.

Conductors and Nonconductors

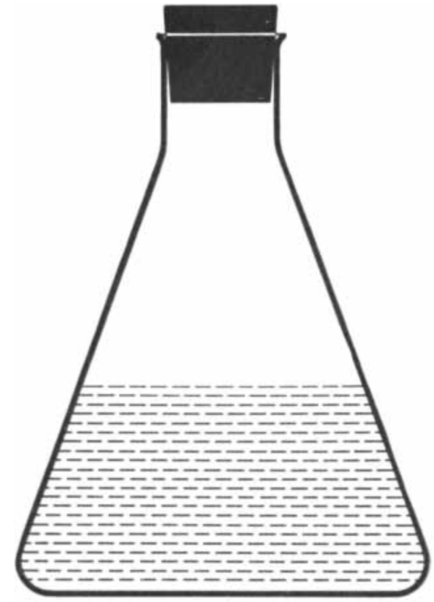
The covalent two-electron bond, the bond achieved by two electrons of opposite spin sharing their wave function, is the most frequent bond of chemistry. It is much more usual than the ionic bond in which an electron is transferred from one atom to another. Its widest application is in organic chemistry. On the other hand, very few crystalline solids are built exclusively on this principle. The classical examples are diamond, germanium and gray tin, a nonmetallic substance. In these crystals the number of nearest neighbors of any given atom just equals its valence. This situation is most perfectly exemplified in the structure of diamond, made up of four-valent carbon. But in general covalent bonding enters into the theory of crystals in a secondary way, in conjunction with other forms of binding.

Implicit in all this is the fact that covalent as well as molecular and ionic crystals are essentially nonconductors of electricity. To be sure, the charged ions in ionic crystals can conduct electricity, but generally their conductivity is small. Electric conduction demands mobile electrons. In these three types of crystals the electrons are all locked into certain quantum states. Metals represent a fourth type of crystal, in which the number of quantum states must be greater than the number of electrons available to fill them, giving the electrons freedom to switch and to move around. For example, in metallic lithium each atom is surrounded symmetrically by eight other atoms. The number of valence electrons per atom is one. If there were no electron spin, one quantum state on each atom would be filled. However, because of spin the number of available states is double the number of electrons, thus giving them a possibility of motion. Because of the electronic charge this motion can be observed as electric current.

In 1900, five years after the discovery of electrons, the German physicist Paul Karl Ludwig Drude suggested that they were the agents which conduct electricity in metals, and he constructed a theory in which he assumed the electrons in the metal to be free, like the molecules in a gas. His theory assumed that the flow of current in a metal depended



FREE ELECTRONS are roughly analogous to water in half-filled vessel.



ELECTRONS IN SODIUM behave like water in vessel that is stoppered.

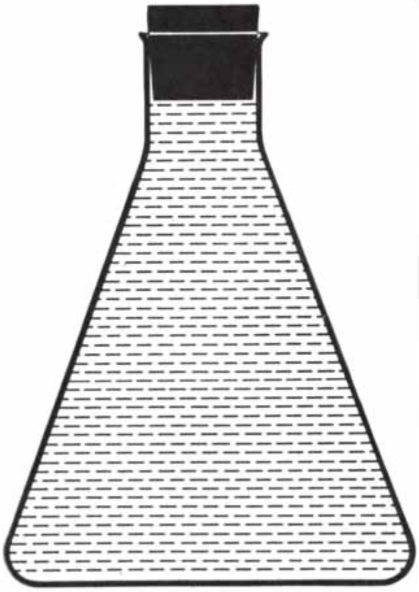
on two factors: the applied electric force and the resistance offered by the numerous collisions between the electrons and the atoms in the metal. Drude's formula was not immediately verifiable because it contained an unknown—the mean free path of the electrons between collisions. However, his theory could be used to calculate the conductivity of heat as well as that of electricity. The ratio between the two conductivities could be computed theoretically and compared with experiment. The result was that theory and experiment checked each other very well.

Yet Drude's theory raised more questions than it answered. One troubling question had to do with the matter of specific heat. If the electrons form a gas, they must obey the laws that apply to gases. The specific heat of a gas is easily computed from theory, because it tells exactly what energy is required to impart to the gas molecules a given speed. These same considerations, applied to a gas of free electrons, predicted that the specific heat of a metal should be larger by a substantial amount than the specific heat of an insulator. But no such difference was found. This contradiction, together with the fact that no criterion was forthcoming to tell when electrons are free and when they are not, stopped further progress. The Drude theory remained a theoretical fragment of doubtful validity which sometimes gave right answers and sometimes did not.

The Electron Gas

The development of quantum mechanics and the enunciation of the exclusion principle resolved the apparent contradiction within the Drude theory. The solution was found in 1928 by Arnold Sommerfeld of the University of Munich. Applying quantum mechanics to the hypothetical electron gas of Drude, he showed that electrons, even at room temperature, are in a condition where all low-lying quantum states are tightly occupied. A gas in such a condition is called a degenerate gas. If we try to heat our degenerate electron gas, we find that most electrons are incapable of accepting energy because all neighboring states are occupied. Only a small number of electrons of highest energy can accept heat in the usual way. In many ways the degenerate electron gas inside a metal can be compared to a container filled with water in which the energy is simulated by the height, and Pauli's exclusion principle by the impossibility of two drops being in the same place. What corresponds to the surface level is the so-called Fermi level for electrons. Below the Fermi level all states are filled; above they are all empty. If the container is agitated slightly, only the surface drops can jump up in the air; the other drops are hindered by the ones above them.

A final clarification of the matter was worked out by Felix Bloch, Eugene P. Wigner and Frederick Seitz, now respectively at Stanford and Princeton Universities and University of Illinois. They studied chiefly sodium. Think of the metal as arising from a gradual pushing together of independent atoms. As the atoms approach one another, they arrive at a distance at which the valence electrons can jump from atom to atom. De Broglie's relation then enters into play: each electron tries to reduce its energy by spreading its wave function uniformly over the entire metal. But according to the Pauli exclusion principle only two electrons in the entire metal can do so. The other electrons have to accept states with shorter wavelengths and a correspondingly smaller binding

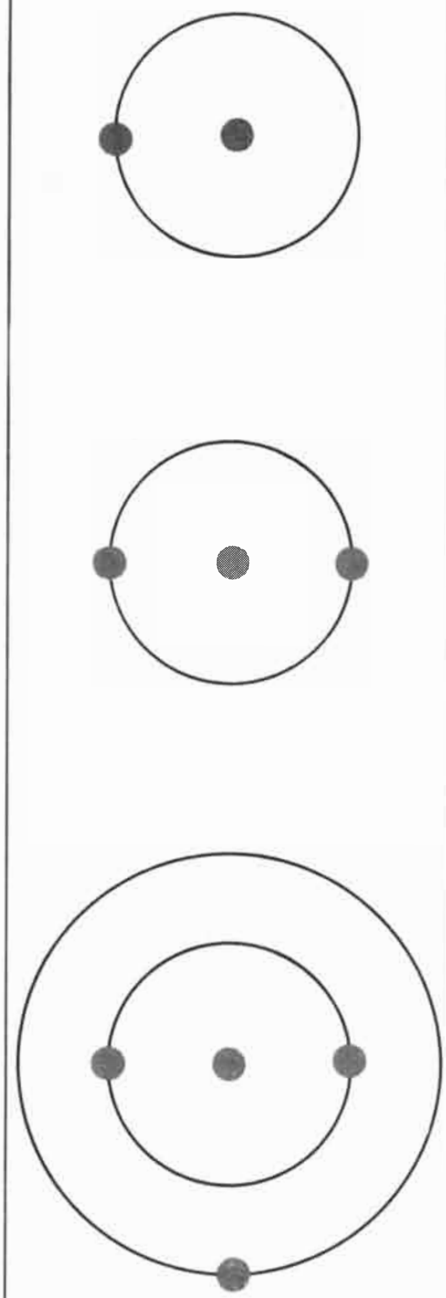


ELECTRONS IN DIAMOND behave like water in filled, stoppered vessel.

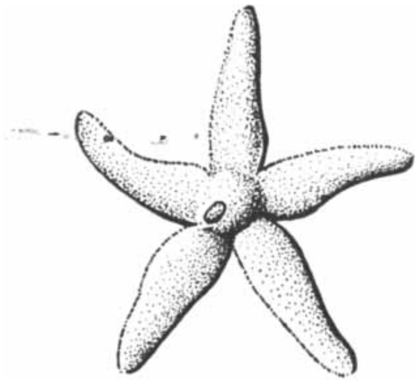
energy. Thus the electrons are piled on top of each other just as in the degenerate electron gas. The totality of states available to these electrons occupies a band of energy, and the filling occurs to a certain level. In the case of sodium there are exactly twice as many possible states as electrons, because there is one electron per atom outside a closed shell and two possible directions of spin. The metallic binding is a consequence of this sharing of electrons, and the conductivity a consequence of the incomplete filling of the available energy levels.

Returning to the water-in-the-container picture, we would say that the electrons in sodium are analogous to a bottle half filled with water, whereas the electrons in a valence crystal like diamond correspond to a full bottle. Finally the picture of free electrons is analogous to water in an open container. So long as the container, whether open or closed, is only partly filled, a slight tilting of the bottle—which simulates the effect of an applied static electric field—brings about a rearrangement of the electrons, emptying certain states and filling others. The filled bottle, on the other hand, shows no response. Thus a close analogy exists between free electrons and electrons in a partially filled band. It is clear that we are dealing with an analogy only; there is no guarantee that it is a perfect one. Indeed, we know it is not quite perfect, for to make it work one sometimes has to ascribe to electrons in a metal an artificial mass which is not their true value. But apart from this the analogy works rather better than one would have a right to expect.

The band into which the quantum state of the valence electron in sodium spreads out is only an instance of a more general feature applicable to all quantum states of an atom when they are brought together. In a solid each atomic state becomes a band, with the lower ones generally narrower than the upper ones. Somewhere within this system lies the Fermi level. Below this level all energy states are filled; above it all are empty. If this level falls within a band, the body is a conductor; if it falls in a gap between bands, it is an insulator. We may say that the solid is similar to a bottle consisting of separated sections connected by narrow tubes. The water



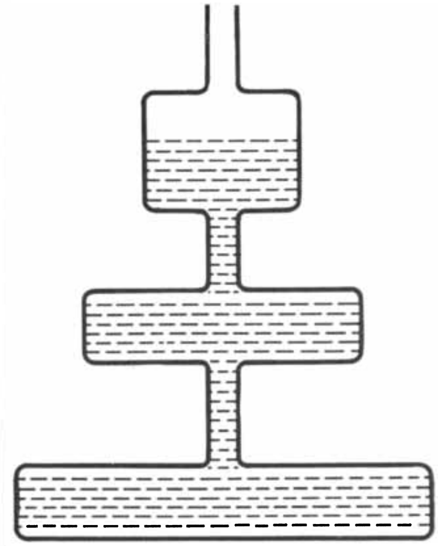
ELECTRON SHELLS account for the repetition of chemical properties in the table of the elements. Hydrogen (*top*), has one electron traveling in one shell. Helium (*middle*) has two electrons which fill shell. Lithium (*bottom*) has third electron which travels in second shell.



FIVE-FOLD SYMMETRY of biological forms is never found in crystals. At top is a five-armed starfish; at bottom a six-sided snow crystal.

level in this bottle may lie within a section, in which case a slight tilting of the bottle can rearrange the regions occupied by the water near the surface (conductor), or it may lie within one of the narrow tubes, in which case tilting will have no effect unless it is very strong (insulator).

The division of solids into conductors and insulators has become complicated in recent years by the observation that all the so-called insulators conduct electricity to some extent. Some of them, called semiconductors, have enough conductivity to be technically interesting. Their conductivity is electronic, but in detail it is quite different from the metallic kind. Metallic conductivity increases as the body is cooled, because of the absence of impeding thermal agitation. Semiconductors, on the other hand, lose their conductivity at low temperature and gain upon heating. The explanation, given by the English physicist Alan H. Wilson, falls into the water-bottle picture developed here. If the tilting or the agitation in the bottle is violent enough, water may be brought up into the empty part, in compensation for which a bubble will appear in the full bulge. In other words, an electron appears in the empty band and a "hole" on the top of the full band. Such pairs,



SECTIONS IN BOTTLE are analogous to energy levels in a crystal.

of electrons and holes, are the carriers of electricity in a semiconductor. Since their number will increase rapidly with temperature, so, therefore, will the electrical conductivity of the material.

Assessing this conductivity one has a very easy time with the "excited" electrons. The Drude theory will apply to them in its original form, because they form a gas which this time is not degenerate; that is, the quantum states adjoining a given one are usually empty. One must not forget, however, the "hole" in the full band. The analogy with a bubble in a full water bottle is a particularly happy one in this connection. The bubble is able to move just as freely as the water in a way we can intuitively understand; it acts as if gravity were directed upward instead of down. In exactly the same sense a "hole" in a full band of negative electrons acts as if it had a positive charge.

Like all sciences that arise late, the physics of solids has the disadvantage of running behind technology. People have used and must use solids all the time, and in doing so, must acquire some sort of technological control over their properties. In such a situation the practical man is apt to despise the dreamers who try to "understand" features which he takes for granted. It looks, however, as if the time for this kind of attitude is about to run out. Theoretical analysis is beginning to produce solids with properties beyond the "common sense" experience of the practical man. The transistor is only one of the spectacular results that are destined to flow from this painstaking study of what has long seemed a dense and commonplace subject.

Gregory H. Wannier is a theoretical physicist at Bell Telephone Laboratories.

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The Social Influence of the Potato

The humble tuber has shaped many cultures, notably the Peruvian and the Irish. For some peoples the richness of its food content and the ease of its cultivation have ironically been a disaster

by Redcliffe N. Salaman

THE potato has had much to do with shaping human society. Two cultures in particular, each in its own way, offer striking examples of its influence. One is Ireland, whose history has been bound up with the potato for more than 300 years. The other is ancient Peru, where for some 2,000 years the potato was not only the staple of life but a spiritual symbol as well. It was from Peru, in fact, that the tuber came to Europe; investigations in recent years have left little doubt that the first European potatoes were of the Peruvian species *Solanum andigenum*. The potato did not arrive in Europe until near the end of the 16th century. It has since been enormously improved. The tuber of today is a triumph of breeding and selection; it differs from its Peruvian ancestor as much as does the race horse from its wild progenitor.

The birthplace of this Peruvian potato, and the place where it was first cultivated, was in the uplands of the Andes between the altitudes of 6,000 and 14,000 feet. In these lofty valleys and plateaus the potato's nutritive value, its bountiful bearing and its good keeping qualities, in an environment where the failure of crops was all too common, made it the pre-eminently suitable food. The pre-Inca Indians who cultivated it were probably the first farmers in history to make a practice of reversing the sod. They worked in teams of at least four persons—two diggers dragging plows to cut the turf, and two others, generally women, following them to turn it over. The Peruvians were also pioneers in the art of preserving food. After harvesting the potatoes they dehydrated part of the crop to keep it for later use. They spread the tubers on the ground and exposed them to the night frosts, then trod them with bare feet during the heat of the day to press out the moisture. After several days of this treatment the potatoes were dried and stored. The product, hard and chalk-white inside and still covered with its brown skin, was known as *chuño*. There was also a refinement of the process in which the potatoes, after the freezing, thawing and treading, were kept in running water for two months. This product, called *tunta*, was snow-white except for the eyes.

THE esteem in which the potato was held by the Peruvians is shown by the fact that they often buried bowls of *chuño*, doubtless as food for the departed, in their tombs, and that in much of their pottery the potato is the motif of the design. I have collected photographs of 70 such Peruvian pots from the museums of the world. Some of them date back to about the time of the beginning of the Christian Era, and the evidence indicates the potato must have been cultivated in pre-Inca Peru as early as 500 B.C.

The potato design on these pots is generally anthropomorphic. It almost always represents a human being, or at least a human head. The design is so cleverly made that it is equally convincing as a representation of a human figure or of a potato tuber. In one pot several tubers are combined to form a head, trunk and arms. All of the figures bear on the head and body many deeply incised tuber "eyes."

Now a peculiar feature of these sculptures is that the human figures are generally mutilated. Of the 27 pots of outspoken anthropomorphic design, 22 exhibit mutilations of the mouth or nose or of both. Sometimes the end of the nose is sliced off; sometimes one or both lips are cut out, so that the teeth appear to sprout from the exposed gums. What explanation is to be ascribed to this curious syndrome—potato tuber, human figure, facial mutilation?

We start with the assumption that the pots depict a sacrificial mutilation designed as a fertility rite to further the productivity of the plant. The germinal foci of the potato tuber lie in the "eyes," and it is a common tradition that a well developed "eye" and a strong bud issuing from it are favorable omens for a bountiful crop. Let us now suppose that the Peruvians regarded these foci not as "eyes" but as "mouths." For this there is morphological support. The "eye" of the more commonly grown *S. andigenum* varieties is very deep, and it is bordered above and below by bolster-like swellings which might be described as lips. From between these lips project the buds, which we must now regard as teeth.

Accepting this symbolization, it follows that the bigger the mouth and more prominent the teeth, the better the prospects for a good crop.

The Peruvian was a confirmed animist. The spirit of the potato, *Papa mama*, needed not only invocation but guidance and strength to carry out its task. A common symbol of strength-giving in primitive rites is the outpouring of blood, and in this case it would have followed the mutilations.

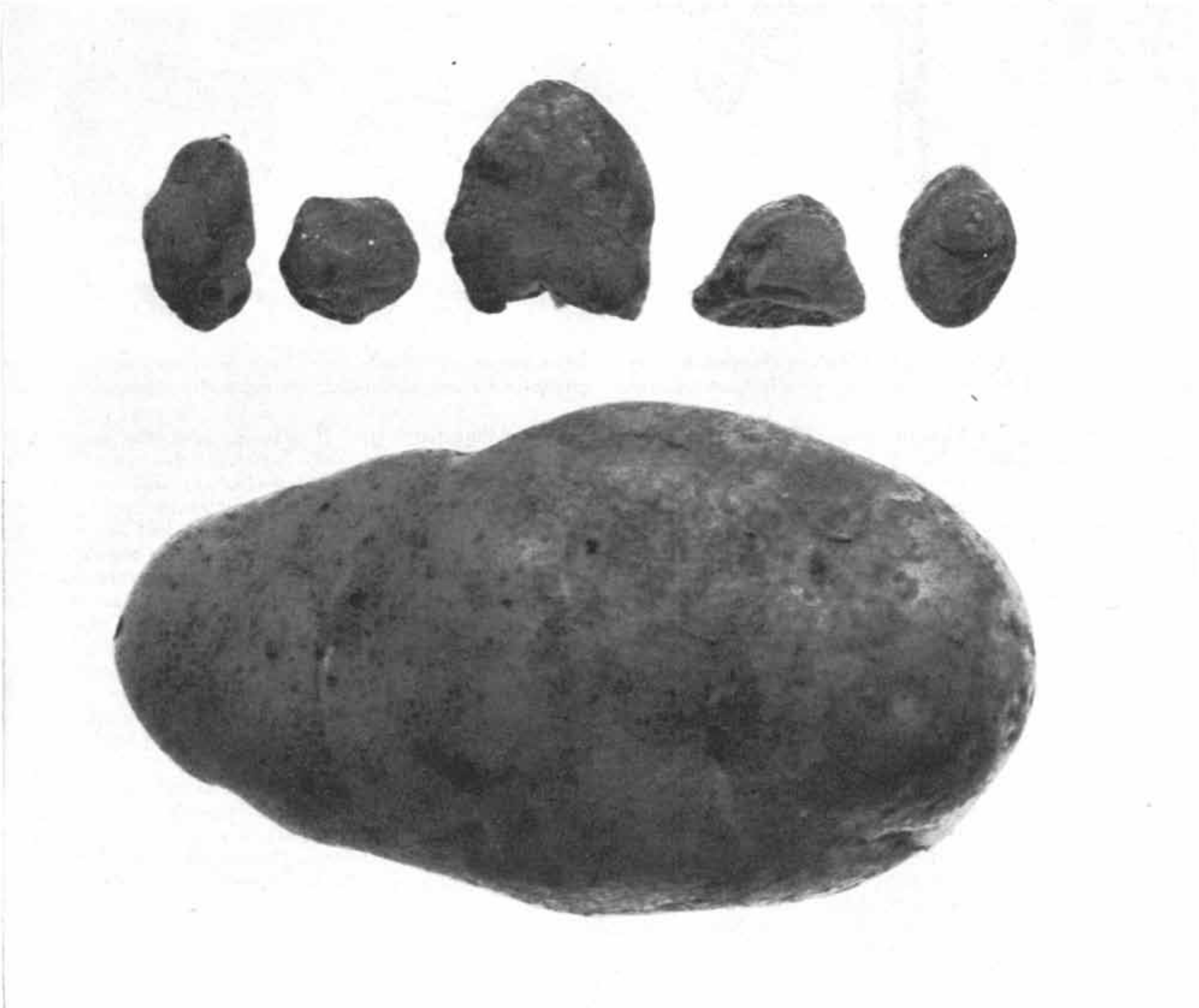
It may be objected that this explanation is an armchair theory lacking factual support. Happily such criticism can be met. We have evidence on the point from the early Spanish soldier Cieza de Léon. In 1545 he witnessed in Inca Peru an elaborate ritual in which the blood of a llama was poured over the seed potatoes before planting. Later visitors to Peru described scenes in which the womenfolk collected the blood of warriors and carried it off to pour on the potato fields, or soaked *chuño* in the blood and ate it. Potatoes of a blood-red color were, and still are, highly prized in the Peru-Bolivia region. Travelers have told me of seeing a curious ceremony: upon finding a blood-red tuber in the field, a farm man or woman rushes to the nearest person of the opposite sex and hits or touches him in the face with it.

The pots themselves give further support to the fertility-symbolism theory. One of them shows not only several mutilated heads of human beings (formed from tubers) but also a large jaguar's head, with mouth open and teeth displayed, as if reinforcing the symbolism suggested by the mutilated heads. Finally, there is an early Mochica pot which seems to sum up the whole story: we see a man built up from a potato tuber, with his lips and the end of his nose cut off and his body bestrewn with "eyes" from which extrude well developed buds. In the man's hand is the digging-stick with which he will plant the tuber seed.

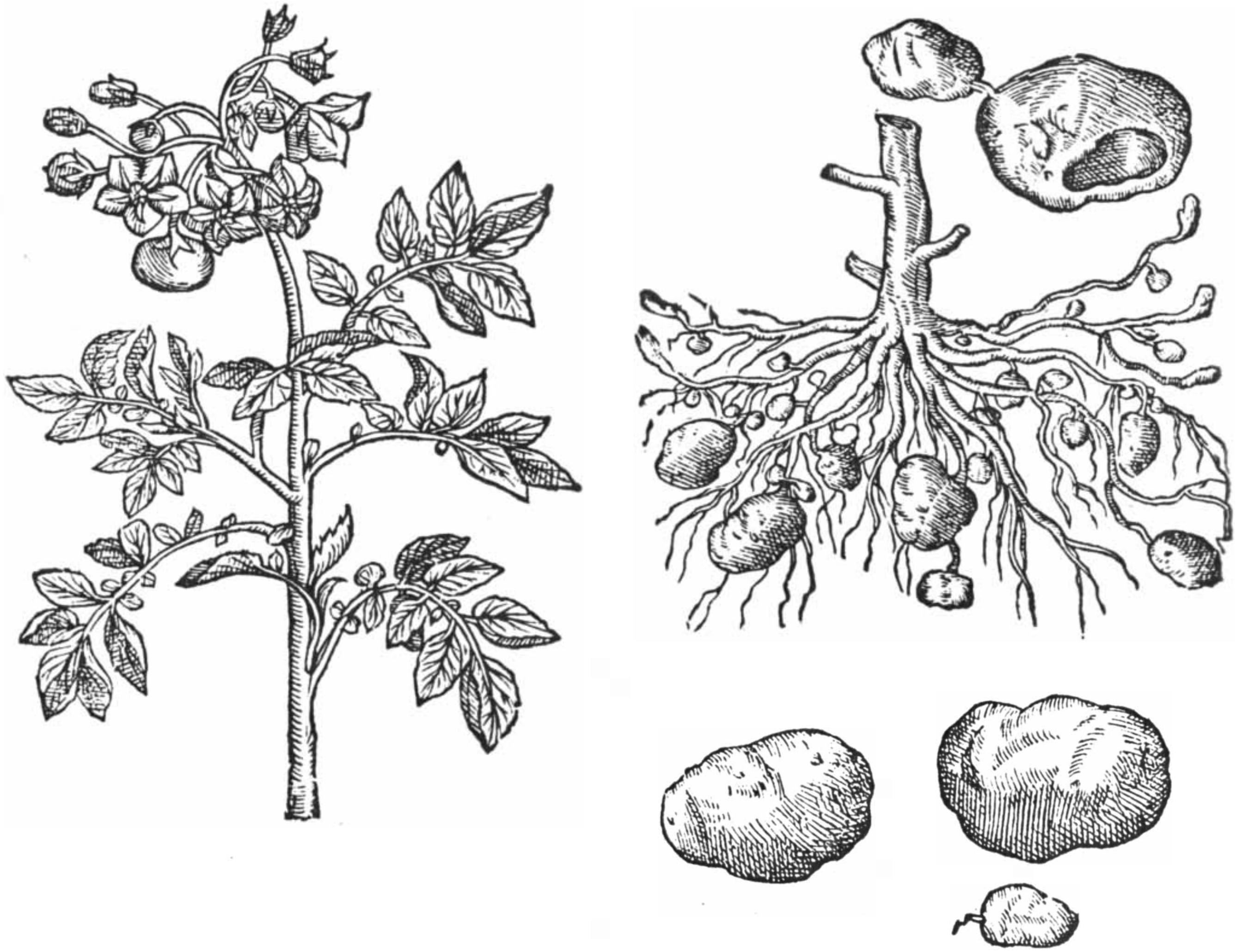
WHEN the potato arrived in Europe, it soon acquired a semi-religious aura there too, but in reverse—the people regarded it as a sinister creation. The Highlanders of Scotland, objecting violently to the tuber as a food, noted significantly that the potato was not mentioned in the Bible. In Russia a century later the introduction of the potato met with open revolt. The Church of the Old Believers wove a nexus of myth around the tuber which, by a miracle of inductive logic, led them to alter the Ukrainian name for a potato, *bulba*, into *gulba*, which connoted something sexually perverse and unclean. England's John Ruskin, in his *The Queen of the Air*, called the potato "the scarcely innocent underground stem of one of a tribe set aside for evil." Throughout the 17th and the 18th centuries there was a widespread and persistent belief that the potato induced leprosy. When that fell disease no longer aroused popular fear, the potato was accused of being the cause of scrofula.

But the tuber was eventually accepted everywhere. It is in Ireland, the classic land of the potato, that one finds the clearest evidence of the influence which a cheap, nutritious foodstuff can exercise on a society. The potato reached Ireland around 1588. The Desmond Revolt at that time and the Cromwellian storm in the mid-17th century uprooted the Irish peasantry and destroyed their herds, their homes and their crops. But by the end of the 17th century the potato had helped them to recover. In Munster and Connaught it had become the basic food of nine tenths of the population. In 1672 John Beale recorded that "potatoes were a relief to Ireland in their last famine; they yield meat and drink"—a signpost on the road along which the Irish economy was traveling. As we journey through the next two centuries, how often we hear the potato spoken of as the lifeline of the people, the trusted bulwark against ever-recurring failures of the cereal crop!

The Irish potato economy has been held partly responsible, and I think rightly, for the rise in population which,



OLD AND NEW POTATOES are compared in their actual size. At the bottom is a modern specimen. At the top are ancient Peruvian *chuños* in the American Museum of Natural History. They were dried by freezing.



FIRST SCIENTIFIC DESCRIPTION of the potato was published in 1601 by the famous French botanist Carolus Clusius, or Charles de l'Escluse. This woodcut is reproduced from his book *Rariorum Plantarum Historia*.

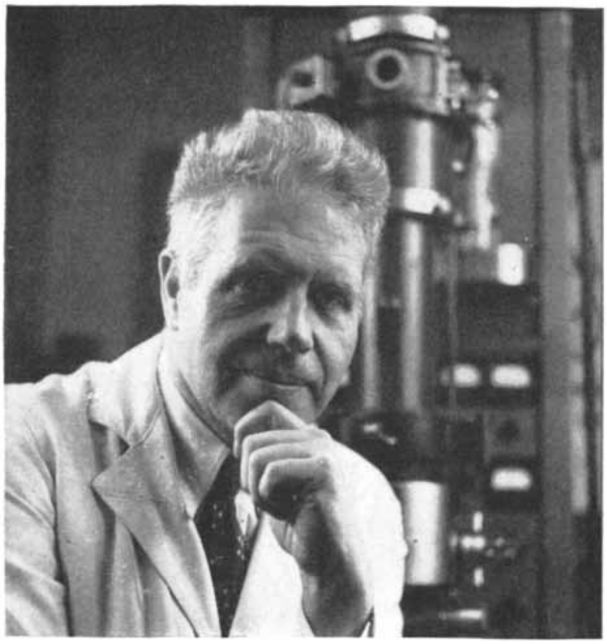
setting in early in the 18th century, was to assume alarming proportions toward its end. It is not true, as was once thought, that the potato has aphrodisiac powers, but it may fairly be said that the potato did a great deal to make large families possible. It provided a maximum of sustenance with a minimum of labor. When the potatoes had been earthed up in early June, there was nothing to do until October, and even then tubers were often left in the ground to be lifted as required—a custom which proved of great value in times of "trouble." The output of an Irish acre was sufficient to supply a married couple and four children with all they needed in the way of potatoes and still leave enough for the pigs and hens, notwithstanding that the average man consumed 12 pounds, the wife 10 pounds, and each child 5 pounds per day.

If food was no limiting factor, neither was clothing; no one wore shoes, and the children ran naked, at least in summer. Housing was of the simplest: it was commonly allowed that a single-chambered black hut could be erected for £3, and a partitioned dwelling for £5. Of furniture there was little more than the three-legged iron cauldron, a few rough stools and perhaps a table. Beds, as such, were a luxury; a straw mattress on the raised part of the floor sufficed. The cow, the pig and the poultry lived under the same roof, providing welcome heat in the winter months. Why, then, should the poor delay marriage, seeing that they couldn't be poorer and might well be happier?

TOWARD the middle of the 18th century a disturbing sign appeared: here and there the potato crop began to fail. Sometimes the cause was excessive rainfall, sometimes drought. And then in 1809 a virus disease struck the crop. By 1817 the disease had brought famine and typhus to the people. The government began to spend large sums for organized relief. In 1833 virus diseases of the potato caused a spurt of emigration to the U. S.

These failures of the potato crop led many to warn the government and the people against undue reliance on the potato. It was too late; the potato had not only fashioned the pattern of the people's lives but also widened the gulf dividing the Protestant ruling caste from the Catholic workers and farmers. The impoverished and subject population felt that its refuge and protection was the potato economy. The relations between the working classes, the small bourgeoisie and the Protestant ascendancy had become so stereotyped, so firmly embedded in an economic nexus in which the potato was the least common denominator, that the people were held in bondage to it.

Then in 1845 and 1846 came the total destruction of the potato crop by the previously unknown fungus *Phytophthora infestans*. The tale of this fatal mold and of the Great Famine that followed has been told too often to need repetition here. Notwithstanding a sustained effort by the government and the people of England to meet the emergency, death and emigration reduced the population of Ireland from 9 million to 6.5 million within six years, and in a couple of decades it had fallen to 4 million.



Adventurers in Research

Dr. Earl A. Gulbransen

SCIENTIST

A graduate of State College of Washington, Pullman, Washington, he received his Ph.D. from the University of Pittsburgh in 1934. He was a National Research Council Fellow in physical chemistry, and later a Research Associate at the University of California. For four years he was Instructor at Tufts College. In 1940 he came to the Westinghouse Research Laboratories as Research Engineer, and in 1947 was advanced to Advisory Engineer, his present post.

When he came to the Westinghouse Research Laboratories in 1940, Dr. Earl Gulbransen was given a challenging assignment. He was asked to initiate a program of fundamental research on the corrosion and oxidation of metals. A new approach was needed. Previous research had failed to solve the problems. Dr. Gulbransen, a physical chemist, was chosen to supply that new approach.

With complete freedom to proceed in any direction he saw fit, Dr. Gulbransen developed a host of new techniques and methods that have resulted in a better understanding of corrosion. He has a unique ability to apply physical tools to the study of chemical reactions. He developed a vacuum microbalance so sensitive that it can weigh a single layer of oxygen atoms . . . a special electron diffraction camera for the study of crystal structure of corrosion films at high temperatures . . . new applications for the electron microscope in the study of chemical reactions on solid materials.

The achievements of Dr. Gulbransen may also be measured by the many honors he has received and his 50 scientific papers published since the start of his research program. His latest honor was from the American Society of Corrosion Engineers, which, at its Spring meeting of 1952, granted Dr. Gulbransen the Willis Rodney Whitney Award for his contributions to the knowledge of corrosion.

Dr. Gulbransen is a soft-spoken, friendly man with intense interests in both technical and cultural directions. He points out that the research in which he is engaged has tremendous social significance. "It is well known that our metal resources are diminishing," he says. "The pressure for these resources in the past has led to power politics and disastrous wars. Success in corrosion research and subsequent practice of protection of our metal resources can offer a real alternative to the pressing problems of mankind."

Dr. Gulbransen will tell you he considers fundamental research the most useful research. He explains that by gaining an understanding of the basic reactions involved between the simple gases and pure metal, an important step is taken toward ultimate solving of the problem of corrosion.

His contributions to science have been many. His practical solutions to problems have added greatly to our knowledge of metal processing, and have resulted in many improvements in Westinghouse products.

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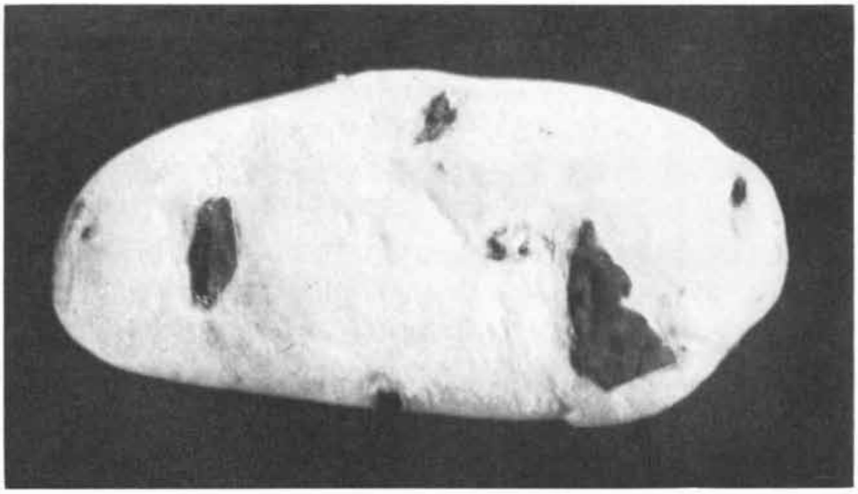
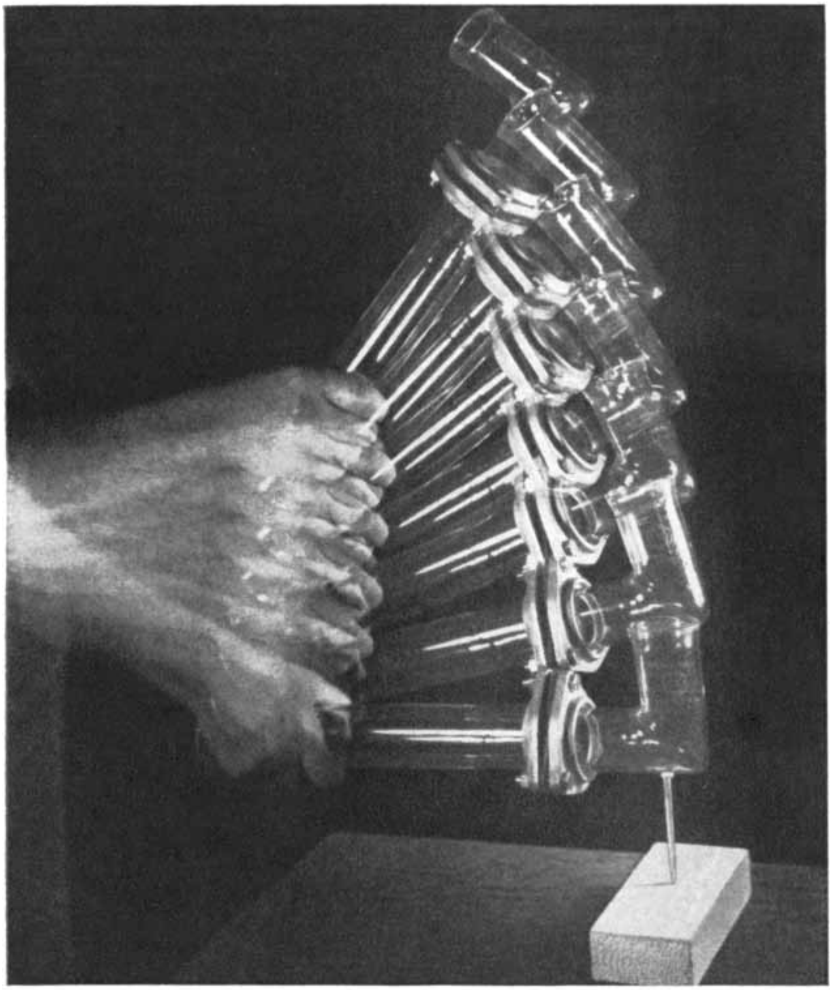


PERUVIAN POTATO called the *tunta* is white except for the eyes. It was made from the already dried *chuño* by long immersion in running water.

The common idea that Ireland attained its economic and political independence by political action and revolution is, I believe, but half the truth. Ireland could never have been really independent until it freed itself from its economic thralldom to the potato. That was not effected by legislation, violence or famine. The old economy was defeated by a newer economy, by free trade and by the importation of cheap American food.

IRELAND is the extreme example of the impact of the potato on social organization. In most of England its effect

PERUVIAN VESSEL was made to look like the *tunta*. Most of the Peruvian potato vessels, however, also look like people (*see photograph on page 56*).



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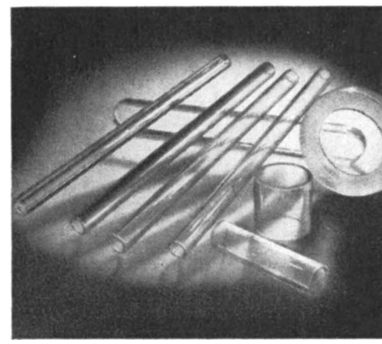

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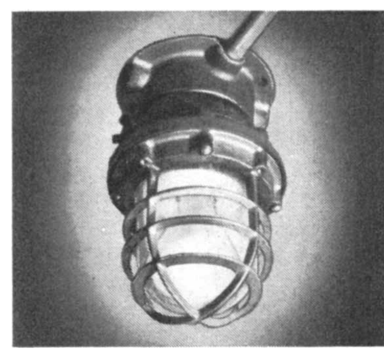

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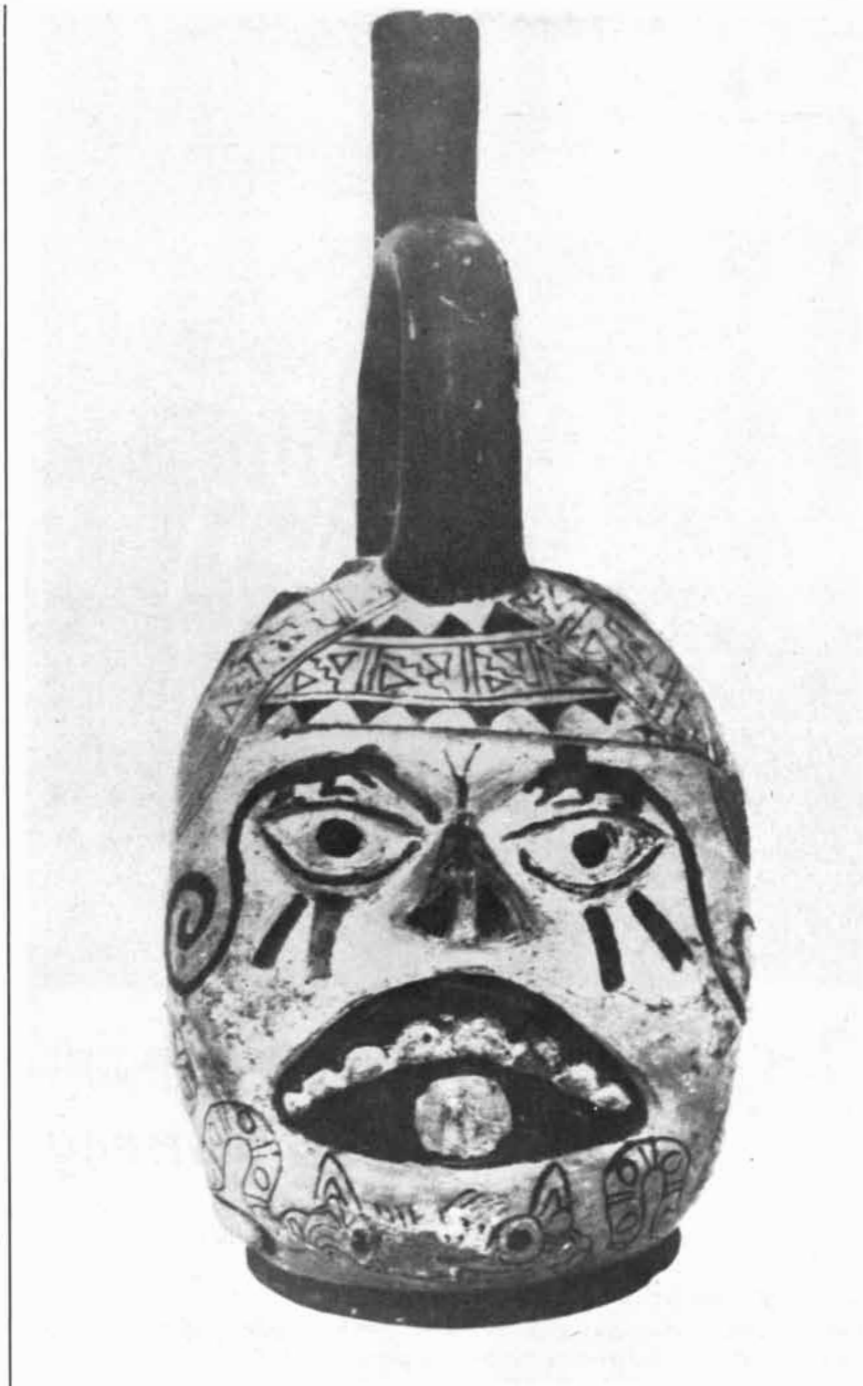


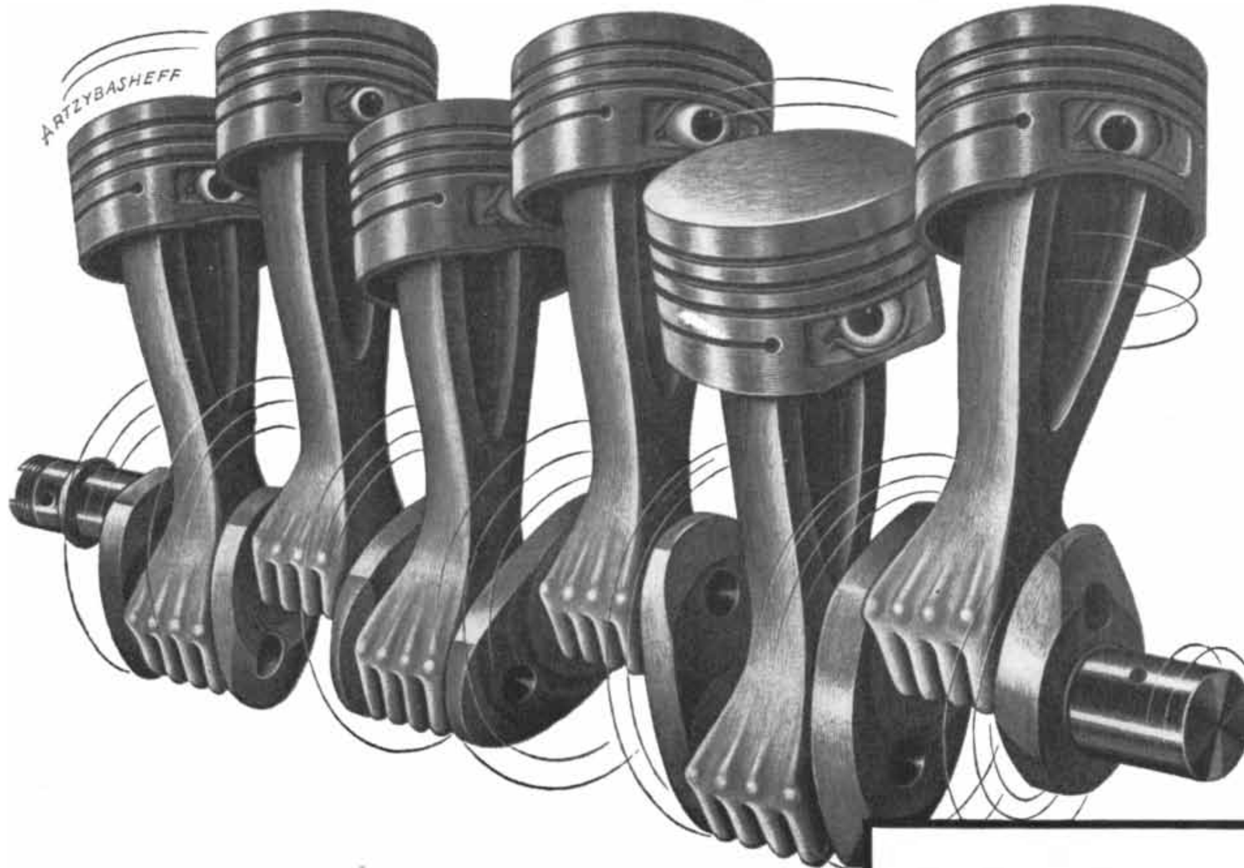
MUTILATED HEAD is worked into the potato design of another Peruvian vessel. The mutilations may have suggested bleeding, symbol of strength.

was blunted by the sturdy independence of the people; in truth the potato there was for a long time a luxury food, and was accepted by the industrial workers only reluctantly after wheat prices skyrocketed during the Napoleonic Wars. The English working man had long regarded the Irishman as a man enslaved by his potato diet, and he struggled to ward off a similar subjection.

The danger the English worker recognized more than 150 years ago has not disappeared. Before World War II a potato economy was being created in rural Poland, and today one exists along part of the Chilean coast of South America and west of it on the Pacific island of Chiloé. As in Ireland just over a hundred years ago, the Chilean crops were destroyed in 1950 suddenly and unexpectedly—and by the same agent.

A cheap, abundant and easily raised food still has its dangers!

Redcliffe N. Salaman is author of the book The History and Social Influence of the Potato.



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THE BREEDER REACTOR

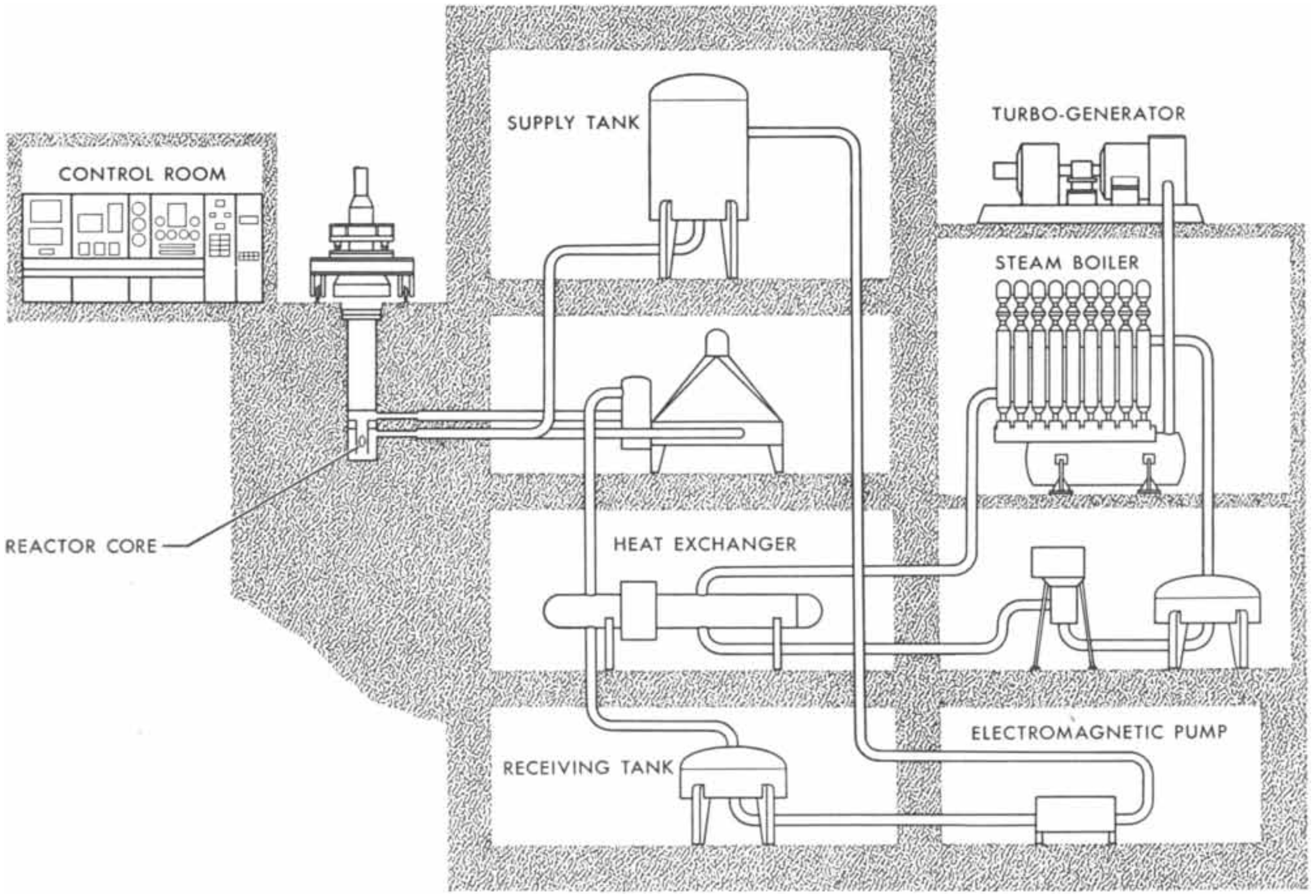
The realization of cheap atomic power hinges on our ability to build reactors that make more fissionable material than they burn. Some details of our first attempts to build one

SEVERAL months ago the Atomic Energy Commission put into operation at Arco, Idaho, its experimental breeder reactor—the first reactor in the world to begin testing the possibilities of harnessing atomic energy as an economic, competitive source of power. As such, it is probably the most important reactor since the original Chicago pile. Its general design has now been made public by W. H. Zinn, director of the Argonne National Laboratory, and a schematic drawing of the design is published below.

The Arco breeder is exploring the answers to several questions, but the key one is whether a nuclear reactor can be made to manufacture more fuel than it burns. Its assignment is to burn the fissionable U-235 in natural uranium and, with the neutrons from these fissions, to convert the much more abundant U-238 in the mixture to fissionable plutonium. The fission of U-235 atoms releases an average of 2.5 neutrons per atom. One of these neutrons must be captured by another U-235 atom to maintain the chain reaction; for breeding to succeed, better than one of the remaining 1.5 neutrons must be captured by U-238 to make plutonium.

The experimental breeder is designed to cut neutron losses to a minimum and ensure that as many as possible find their way to U-238 atoms. Its reacting core is tiny—about the size of a football. Because the materials used in a reactor to slow down neutrons all absorb some neutrons, this reactor has no moderator: it operates with fast neutrons. Around the core is a "blanket" of U-238, which catches neutrons to form plutonium.

All of the reactor's power is generated as heat in this small core. The coolant that picks up the heat and carries it to the electricity-generating unit is a liquid metal—an alloy of sodium and potassium. This alloy does not appreci-



SCHEMATIC DIAGRAM shows reactor together with its associated energy-converting equipment. Wide gray borders indicate concrete shielding which encloses the core and radioactive primary cooling circuit. In the heat exchanger a secondary circuit takes heat (but not radioactivity) and conveys it to the unshielded steam boiler. Space used for energy production is seen to be tiny compared with the space for energy conversion.

RADIATION DAMAGE crumbles fuel element. Before-and-after views show effect of neutron bombardment.

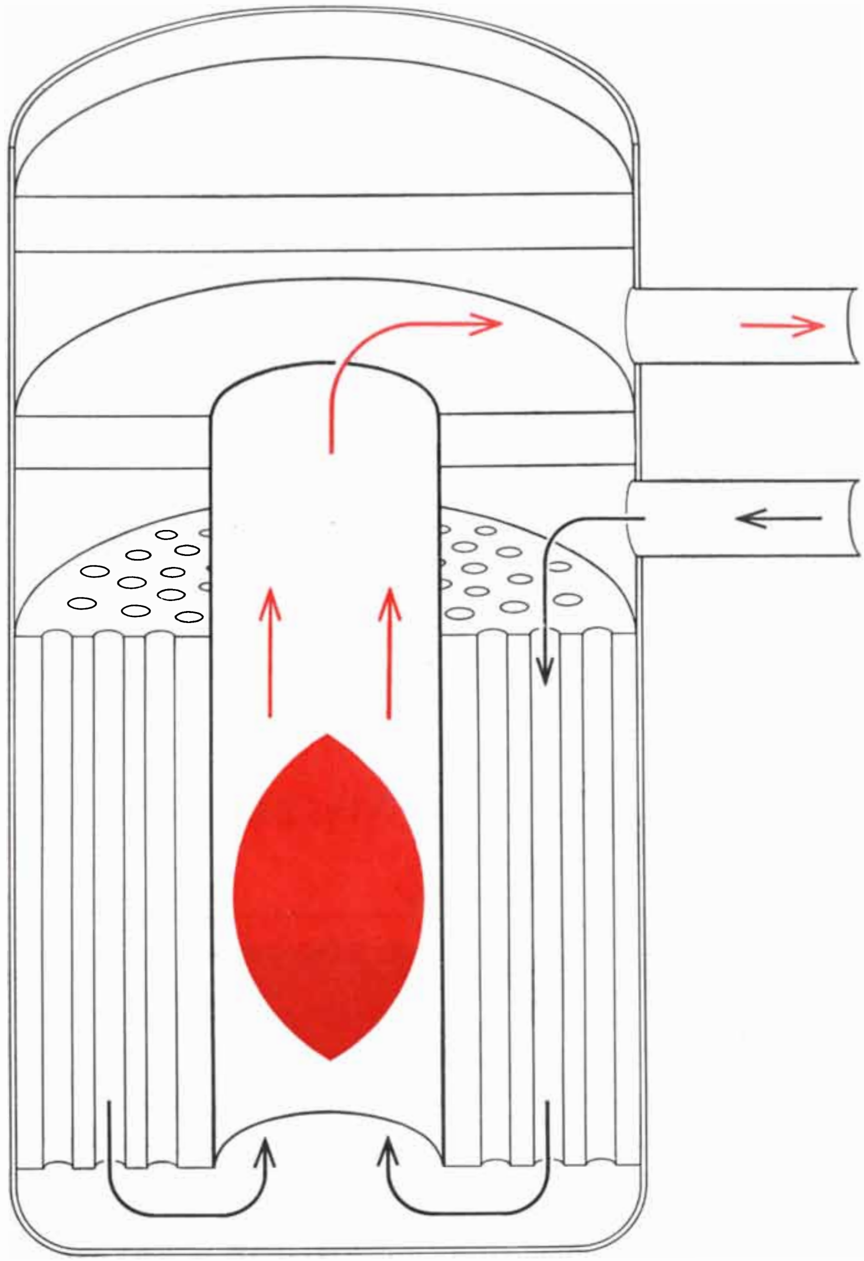
ably absorb neutrons and has excellent characteristics as a heat transfer medium: for example, it is liquid at room temperature but has a high boiling point, 1,500 degrees. It is, however, extremely active chemically: it burns vigorously when exposed to air and explodes on contact with water. It is also highly radioactive because of its exposure to neutrons. Hence it must be handled carefully. Emerging from the core at a temperature of 660 degrees, the coolant flows through a heat exchanger, where it gives up its heat to a second circuit, and is then pumped to an elevated storage tank, from which it begins its circuit again. To handle the radioactive liquid metal, special pumps, valves, flow meters and other instruments had to be designed. One of these is a unique "electromagnetic pump" without moving parts. It operates much like an induction motor: electromagnetic forces move the liquid metal through a duct in the same way that they force the rotor of an induction motor to turn.

The section of the plant through which radioactive coolant flows is enclosed by a concrete shield. The second circuit of sodium potassium alloy, which takes the heat from the first, does not become radioactive and is outside the shield. It transfers the heat to a steam boiler of special design. With sodium-potassium alloy and water together in the same apparatus, the boiler must be constructed so that they cannot come into contact with each other.

THE REACTOR core has the highest flux of neutrons known—650 million million neutrons per square inch per second. This creates a severe problem, because a high neutron flux breaks down the physical structure of all materials and equipment exposed to it, including the uranium itself (*see photographs above*).

The AEC has not disclosed how heat can be transferred efficiently from the very small reactor core. The reactor yields four kilowatts of power for each cubic inch of the core, whereas a modern oil-fired naval boiler gives only six tenths of a kilowatt per cubic inch.

The experimental breeder is producing enough power to supply its own



CORE AND BLANKET are shown in close-up. Chain-reacting core (*red oval*) supplies neutrons to surrounding U-238. Liquid metal coolant flows through blanket and core and emerges (*red arrows*) at 660 degrees.

electrical machinery. But there is no indication that it has yet attained its primary goal—breeding more nuclear fuel than is consumed. "We do not know," says Zinn, "that we can operate a reactor in which the necessary economy of neutrons exists. . . . Perhaps more such experimental devices will be necessary before we are on sure ground as to the fundamental feasibility of the process."

If breeding does succeed, and despite their cautious tone most authorities believe that it will, Zinn points out that 20 pounds of natural uranium will yield 51,800,000 kilowatt-hours of electricity—enough to light 25,000 average American homes for a year. At an assumed price of $35 a pound for refined uranium this gives a fuel cost of .013 mills per kilowatt-hour exclusive of the cost of chemical processing to separate the plutonium. Even if fuel processing raises the cost by a factor of 10, Zinn observes, the fuel cost will still be negligible.

A NUMBER of private industrial firms are now studying the possibilities of commercial atomic power. The Dow Chemical and Detroit Edison group recently indicated that it thinks breeding is a good bet to succeed. This group proposes to build a pilot power plant using a high-temperature breeder reactor. It has said that it is willing to undertake the project with its own funds and without a government-guaranteed price for plutonium made in its plant.

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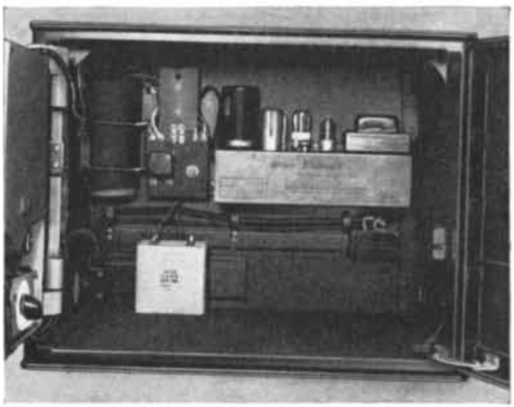

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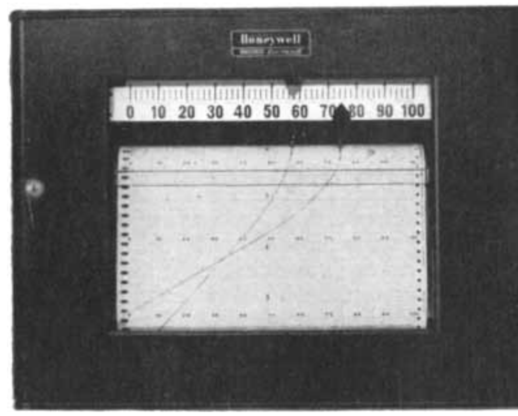

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TRAUMATIC SHOCK

The dangerous complication of serious injuries is countered by transfusion, but not always successfully. An experimental study of such failures suggests a hitherto unsuspected cause

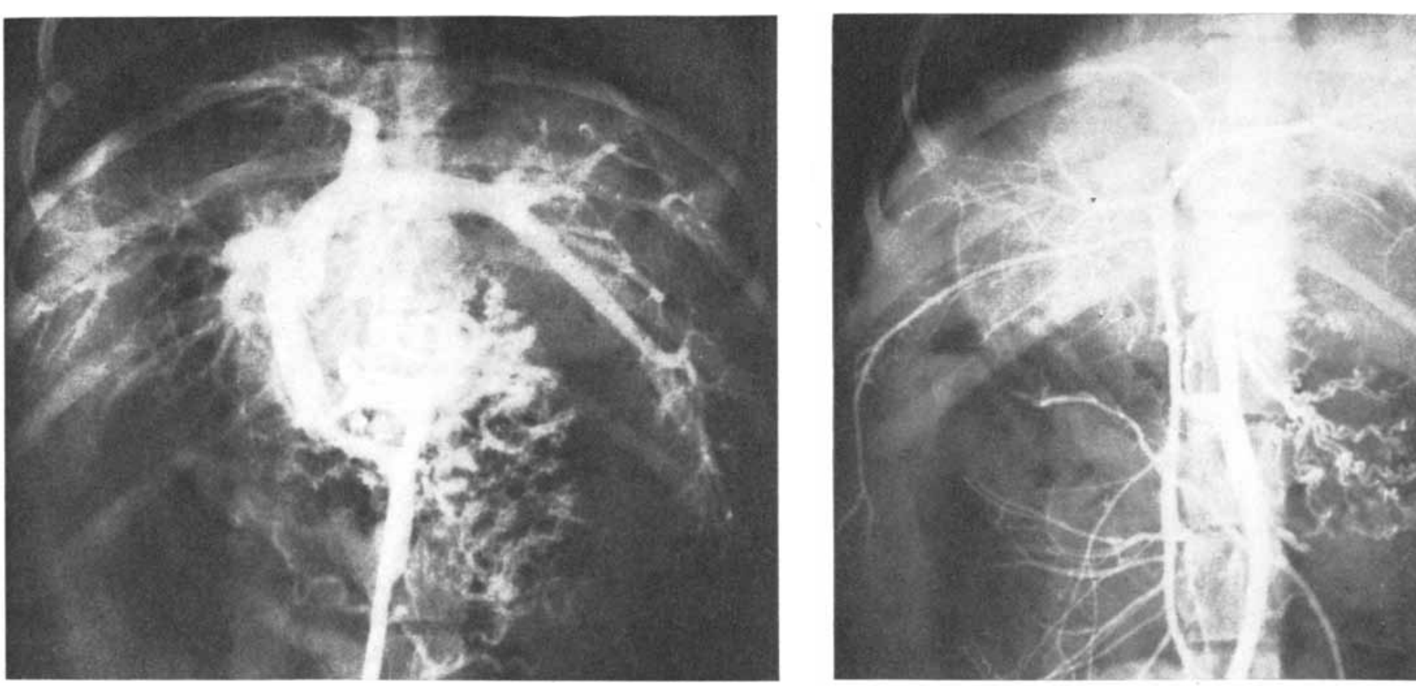
by Jacob Fine

TRAUMATIC shock is a serious, often fatal, complication of major injury. Since it usually occurs when the victim has lost a considerable quantity of blood, the standard treatment is to replace this blood by transfusion. However, transfusions do not always work, and for many years investigators have been studying the problem of just what happens in shock and how it might be treated more effectively. This is an account of current studies at the Harvard Medical School and elsewhere which have yielded some promising leads.

A person suffering from traumatic shock due to loss of blood is in an obvious state of collapse. The lips and skin are pale; the skin is cold and moist; the blood pressure is low; the pulse is fast; there is no urine. The deficiency in the supply of blood to the tissues leads to rapid disintegration and death within hours, or at most one or two days. Replacement of the blood loss will usually save the patient, if the transfusion is given soon enough and the major feature of the injury is simply the hemorrhage. But long ago it was learned that often this is not the whole story, that in many cases some factor apart from loss of blood volume must be present, because transfusion is useless. For example, shock caused by extensive burns sometimes is not cured by replacement of the large loss of blood plasma. The same is often true in cases of a massive wound of muscles or viscera, known as "wound shock." The questions arose: Is burn shock or wound shock the same as hemorrhagic shock? What is the factor that prevents shock victims from recovering when they are given prompt transfusions? This was where the problem stood in 1940.

During the past decade it has been attacked in many ways, and one of the most fruitful was an intensive study by Robert Chambers and his colleagues at New York University of the changes in the peripheral circulation during shock. Let us look for a moment at the system of peripheral blood vessels. Approaching the capillary bed that feeds the tissues, the small arteries (arterioles) divide into still smaller metarterioles and the latter in turn branch into capillaries. At the outgoing end the capillaries fuse to form venules and these join to form veins. The inlet (arteriole) and the outlet (venule) of the capillary system are connected by a blood vessel, called the arteriovenous anastomosis, which under certain circumstances allows blood to by-pass the capillaries (*see diagram at the top of page 64*).

The thrust of the heartbeat is not powerful enough to drive blood through the capillary system. The circulation



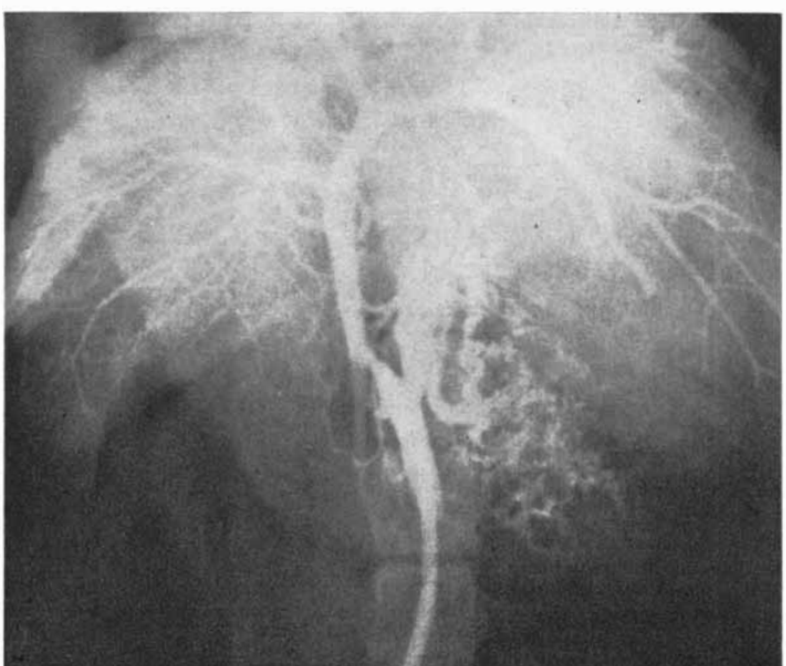
EFFECT OF SHOCK on the portal circulation of a dog is revealed by injecting a substance opaque to X-rays into its circulatory system. The large vessel at left center in each of these X-ray photographs is the portal vein, which conducts three fourths of the blood to enter the liver. At the upper right in the photographs are the there is helped by a sheath of muscle around the arterioles, which contracts rhythmically and so "milks" the blood forward through the capillaries. At the point where the metarterioles branch into capillaries, there is a muscular sphincter which regulates the flow into the capillary system. The blood pressure at the incoming end of the system is substantially higher than at the outgoing end: it falls from an average of 120 millimeters of mercury in the small entering arteries to about 10 millimeters in the outgoing veins.

When the body's blood volume drops sharply, the small arteries constrict, increase their resistance to flow, and so assist in sustaining the blood pressure. The resulting decrease in the flow of blood through the capillaries reduces the nourishment and cleansing of the tissues. The arterial muscle, like all other tissues, suffers from this. Eventually it loses its contracting power. Much of the blood coming to the arterioles is diverted from the capillary system through the by-passing vessel, and the flow through the capillaries becomes swamplike. The oxygen supply falls, and acid products from the tissues accumulate in the blood. Owing to the reduced hydrostatic pressure in the capillaries, the filtration of the blood by the kidneys slows up or stops. Urine is scant or absent, and waste products are not excreted. Before long some vital organ gives way and death soon follows.

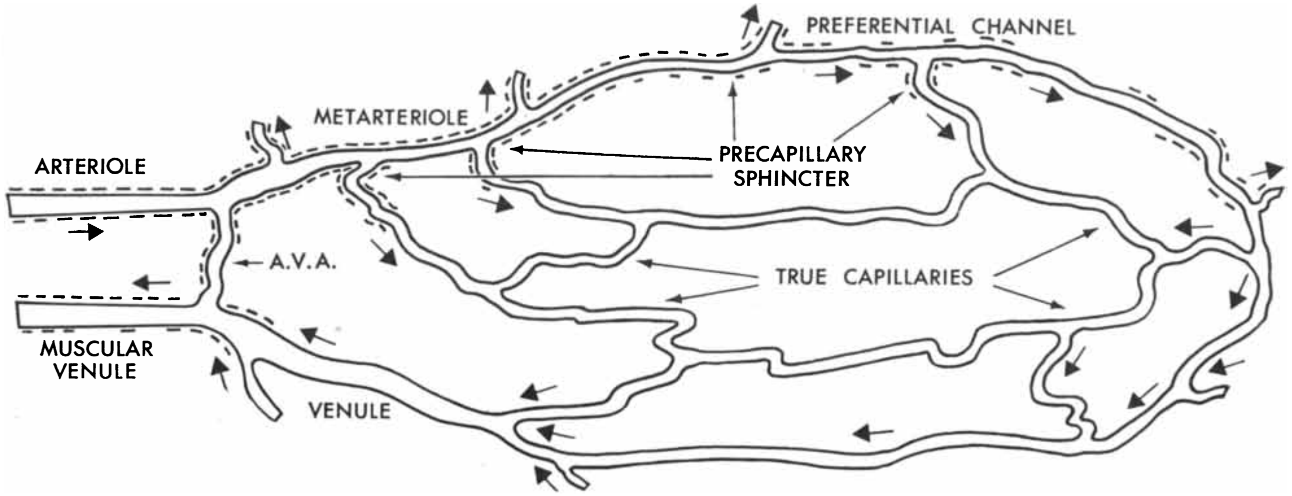
THIS IS the intimate picture of the peripheral circulation in traumatic shock, however produced. The surprising and significant fact is that the same paralysis of peripheral vessels and swamplike slowing of flow in the capillaries occurs even in cases of shock in which there is no significant loss of blood: for example, in persons injured by being buried under a cave-in or in patients suffering a severe infection, such as peritonitis or pneumonia.

What common denominator can there be in all these different situations that causes the same collapse of the peripheral circulation? Many years ago the great Harvard physiologist Walter B. Cannon proposed that a toxin might be the responsible agent. But an intensive search failed to disclose such a factor that would receive acceptance. Even in shock due to infection it is by no means agreed that bacterial toxins are the direct cause. Many investigators have sought to trace shock to the failure of a particular organ or tissue. The literature is full of studies invoking a crucial role for the heart, the central nervous system, the kidneys, the adrenals. Others have looked for the cause of death in a generalized deterioration of cells or in disturbances of enzymatic processes.

The heart came under early scrutiny, because the blood output per beat is always much reduced in shock. This happens whether or not blood is lost, because in both types of shock the reduced velocity of flow in the peripheral circulation results in a slower filling of the veins and a decline in the flow back to the heart. The heart muscle, however, shows greater resistance than other tissues to the ravages of insufficient oxygen or deficiency of flow. At any time up to the moment of death, the heart will respond well to the spur of a fresh



vessels of the liver. The first photograph shows the normal portal circulation. The second photograph shows the same vessels after experimental hemorrhage. The third shows the vessels after the original blood volume had been restored.



CAPILLARY BED is supplied with blood by the metarteriole and drained by the venule. Around some of these small vessels is a muscular sheath, here indicated by short lines. At the left is the arteriovenous anastomosis (A.V.A.), through which blood can by-pass the capillary bed. The diagrams on this page are adapted from the publications of Ephraim Shorr and his associates at the Cornell University Medical College.

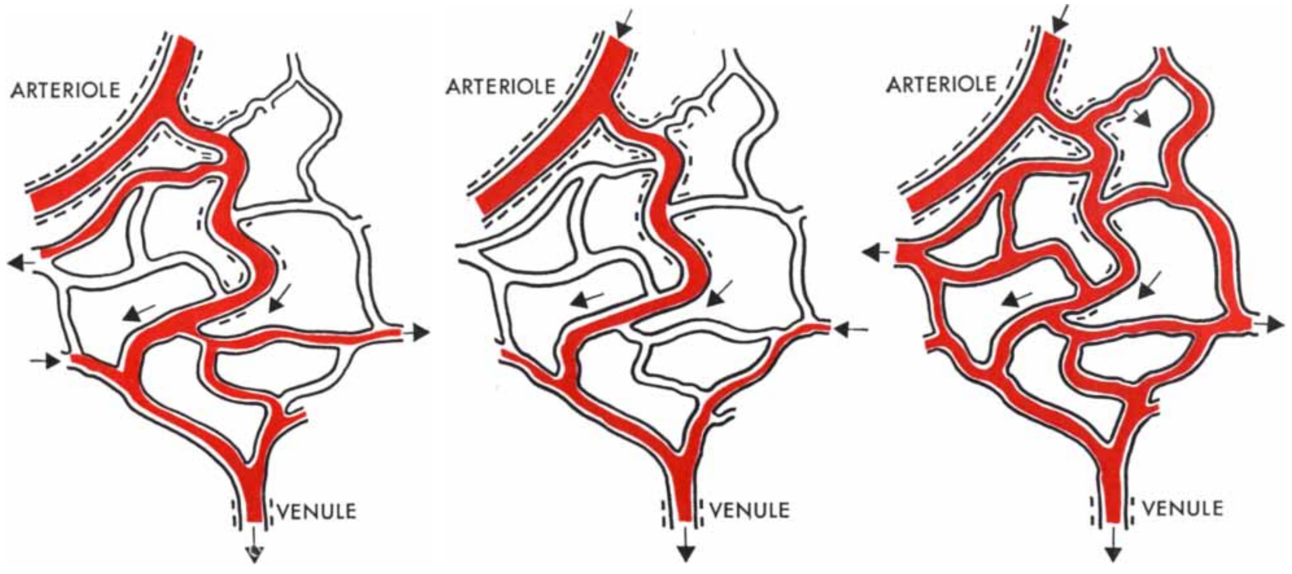
transfusion. Even so, the shock state does not improve; the collapse of the peripheral circulation persists. Hence the heart can be dismissed as the central cause of the state of shock.

The central nervous system also can be excluded, on the ground that its control of respiration, heart action and other vital functions continues in good order to the end. So, too, can the kidneys. It is obvious that they are seriously injured, for urine formation declines sharply or stops altogether. But shock victims may die in a matter of hours, whereas even a total collapse of the kidneys is not fatal for some 6 to 12 days. Moreover, use of the artificial kidney is of no help in shock.

We can also exonerate the adrenals, because traumatic shock is not alleviated by adrenalin, by adrenal extracts, by cortisone or by ACTH, which can correct or compensate for adrenal failure.

Efforts have been made to treat shock by correcting the intermediary metabolism, which is upset by shock in many ways. Inhalation of pure oxygen, intravenous injections of glucose and of alkali, drugs to raise blood pressure, procedures to restore the blood's electrolyte balance and to remove nitrogenous waste products—all these have been found ineffective. If a normal and sustained flow of blood in the peripheral circulation can be brought about by transfusion, these procedures are unnecessary. If transfusion cannot restore normal flow, these procedures prove useless, whether instituted before or after the transfusion.

In 1940 there was a popular theory that in those cases where transfusions failed, the trouble was that the walls of all the capillaries became more than normally permeable, so that plasma and other fluids escaped into the tissues as fast as they were poured into the circulation. The naivete with which this theory was accepted is surprising. Since only plasma, not whole blood, could escape in excess from the circulation, the theory required that the concentration of red cells in the blood should rise. No evidence that this happened (except in special cases such as burns) was ever produced, and eventually the theory



PATH OF BLOOD through the capillary bed is normally routed by muscular sphincters first through one capillary, then through another (*left*). When the blood pressure drops, the sphincters contract so that the blood passes only through the muscular "preferential channel" (*center*). After prolonged low pressure, however, the muscles lose their power to contract and relax, allowing blood to stagnate in the capillary bed (*right*).

was definitely disproved, both by labeling the proteins in the plasma with radioactive tracer isotopes and by measurements, with reliable new techniques, of the blood volume, which showed that almost all the transfused blood remains in the circulation. When plasma leaves the circulation at an excessive rate, it does so only at a site of injury.

EVENTUALLY it occurred to us that one vital organ had not yet been sufficiently investigated. This was the liver. Several things made it an intriguing suspect. Its destruction or removal means death within 24 hours. Unlike other organs, which receive all of their blood from arteries, the liver gets three-quarters of its supply from the portal vein. It was known that during shock the oxygen content of the blood in the portal vein drops almost to zero. We proceeded to investigate how the liver would respond if this deficiency were corrected. We used a special experimental technique we had developed for evaluation of various treatments.

A healthy dog, quieted with a dose of morphine, is gently tied down on a table, and after the skin of the groin has been shaved and novocain injected, an incision is made to expose the large artery and vein in the groin. Into these vessels are inserted glass tubes connected by rubber tubes to an elevated reservoir containing heparin, an anti-clotting agent. The experiment begins when blood from the artery is allowed to run unimpeded into the reservoir. As bleeding proceeds, the blood vessels of the dog progressively constrict to take up the slack caused by the decline in blood volume. The height of the reservoir is adjusted so that bleeding will stop when the blood pressure drops to 30 millimeters of mercury. The dog is now in deep shock. The blood pressure and the blood level in the reservoir remain constant for an hour or so. Then the constricted muscles of the arterioles begin to lose their strength. As the vessels relax and the blood pressure falls, blood flows back from the reservoir into the artery until the pressure again rises to 30 millimeters. The dog has performed a self-transfusion. The blood vessels may recover tone for a time and stop taking up blood, but eventually their capacity for recovering tone declines. Then the self-transfusions become larger and larger. When, in spite of the return of more and more blood, the vessels' tone is so exhausted that they cannot sustain the pressure at 30 millimeters, the blood pressure begins to fall steadily and rapidly. The dog soon dies, even though all the blood has flowed back into its system.

Experience in hundreds of experiments has shown that if, at any time before the dog has taken back 40 per cent of the maximum bleeding volume, the remainder is rapidly transfused into the vein, the blood pressure returns to normal, or nearly to normal. The shock promptly disappears and the dog recovers. If, however, the remainder is not transfused until after more than 40 per cent has been taken back, the dog does not recover. The quantity of 40 per cent is therefore the critical point. Beyond it shock cannot be reversed by transfusion. It is an artificial point, to be sure, since it has meaning only in terms of this particular experimental setup.

The average duration of the period of shock before irreversibility sets in is 4.8 hours, and the maximum volume bled out averages 53 milliliters per kilogram of body weight. These figures will not hold if the experiment is modified in any important respect. Thus, if the room temperature and humidity are high, if the dog has been sick or is malnourished, if an anesthetic or a barbiturate has been administered, the reversible phase will be shorter and the bleeding volume will be less.

With this controlled experiment established, we were ready to begin searching for the factor that produces irreversibility, and to try out various therapeutic agents for treating heretofore irreversible shock.

WE SET about testing the possibility that the liver is responsible for irreversible shock. We supplied that organ with a flow of fully oxygenated blood, while the rest of the body was kept in a state of shock. This was done by connecting two large arteries of a healthy donor dog to the shocked dog's portal vein. A volume of blood equal to that delivered to the liver was simultaneously removed from the large vein in the groin and returned to the donor dog, which was none the worse for wear at the end of the experiment. The shocked dog so treated survived. But if the donor's blood was delivered to an ordinary large systemic vein, say in the groin or neck, instead of into the portal vein, the shocked dog died just as promptly as if it had received nothing from a donor.

This experiment implicated the liver, but we still did not know how the damage was done. X-ray studies of the liver during shock show that the vessels of this organ, as of other organs, are in a state of spasm. As a result, blood in the portal system is partly blocked from returning to the general circulation through the liver. The pressure in the portal vein becomes much higher than in the systemic veins, especially if repeated transfusions have raised the patient's blood volume above normal. However, we found that reducing the pressure in the portal vein did not help; hence the high pressure did not account for the major features of the shock state.

We then considered anew Cannon's old toxin theory. Does shock prevent the liver from manufacturing some substance essential to normal functioning of the peripheral vessels, or cause it to produce a substance injurious to these vessels? Ephraim Shorr and Abraham Mazur at the Cornell University Medical College have reported that the liver in shock, deprived of oxygen, converts one of its proteins into a substance which depresses the peripheral circulation. But they have also found a similar substance in muscle tissue deprived of its circulation. Since bacteria may normally be present in both muscle and liver tissue, there is a possibility that the depressor substance may be a bacterial product. In any case, their work places the theory of a toxic agent on firmer ground than before.

WE DECIDED to re-examine the possibility that the irreversible damage in hemorrhagic shock might be caused by bacteria. Since the advent of the antibiotics, it has been found that these drugs often reverse shock due to infection simply by attacking the infecting agent. There is also the suggestive fact that burns and wounds are as a rule contaminated with bacteria.

We investigated in turn three possible sources of bacterial invasion in our experiments on shock. The first was the apparatus used and the non-sterile incisions made for exposing the blood vessels. We eliminated this possibility by carrying out a series of experiments with all the sterile precautions of a hospital operating room, which did not change the results.

The second possible source was the bacteria in the tissues of the dog. Nearly every tissue in a healthy dog harbors the gas bacillus and sometimes other bacteria. The liver is especially rich in gas bacilli. It was conceivable that this microbe, which flourishes in the absence of oxygen, might begin to produce lethal toxins during shock, when the oxygen supply to the liver falls. But in a series of experiments on more than 50 dogs we found that intravenous administration of penicillin and aureomycin, to which most strains of gas bacilli and many other bacteria are sensitive, failed to prevent the development of irreversible shock in a majority of animals.

The third possible source of bacterial toxin is the intestinal flora. We knew that prolonged irritation of the intestinal wall by exposure to certain irrigating fluids could make it permeable to intestinal bacteria so that they could invade the peritoneal cavity. It seemed possible that the intestinal wall might also become permeable as a result of damage due to lack of oxygen.

In the next series of shock experiments, therefore, we treated the animals beforehand with antibiotics that destroy intestinal bacteria. These treated dogs showed remarkable resistance to irreversible shock. Only six out of 50 died, against the usual expectation of 40

out of 50. Although the treated dogs bled as much as the untreated ones, their period of tolerance to the low blood pressure rose from 4.8 hours to over 7 hours, and even more striking was the fact that after the dogs had passed the 40 per cent critical point, restoration of the full volume of blood brought about a rapid recovery. The next day the dogs were frisky, took food and seemed none the worse for the experience.

We cannot be certain that the effectiveness of the drugs was due exclusively to action on bacteria in the intestines. However, one of the antibiotics we used was neomycin, and only three per cent of this drug, given by mouth, gets into the bloodstream. Moreover, penicillin was much more effective when put into the intestine than when injected. Altogether the experiments strongly implicate intestinal bacteria as the chief culprits in producing irreversible shock. It is at present impossible to say whether the bacteria's effect on the blood vessels is due to their own escape from the intestine into the bloodstream, to the escape of toxins they manufacture or to failure of the injured liver to perform its normal function of neutralizing such toxins. In an effort to account for the beneficial effect of maintaining a normal supply of arterial blood to the liver, we compared the result of infusing aureomycin into the portal vein (through which bacteria from the intestine can reach the liver) with that of infusing aureomycin in a vein of the general circulation. The results suggest that the bacteria reaching the liver via the portal vein from the intestine are the most important source of the substance which damages the vessels; the liver in shock apparently loses its capacity to destroy this substance.

Of course the findings in these experiments do not necessarily apply to man. We do not know whether invasion of intestinal bacteria occurs in man during shock. The most significant result of the experiments in dogs, however, is the general observation that bacterial action appears to account for irreversibility to transfusion, even when there is no evidence that bacterial action is taking place. A shock-producing wound, whether obviously infected or not, is likely to harbor bacteria. The most devastating wounds are those of the buttocks and lower extremities, the skin of which harbors intestinal bacteria.

Tentatively it is our conclusion that when traumatic shock does not yield promptly to transfusion, infection should be assumed, and antibiotic therapy should be tried.

Jacob Fine is professor of surgery at the Harvard Medical School.

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Arroyos

A century ago the valleys of the Southwest were green; now they are brown and cut by gullies. Man is blamed for the change, but he has only added a factor to the geologic cycle that causes it

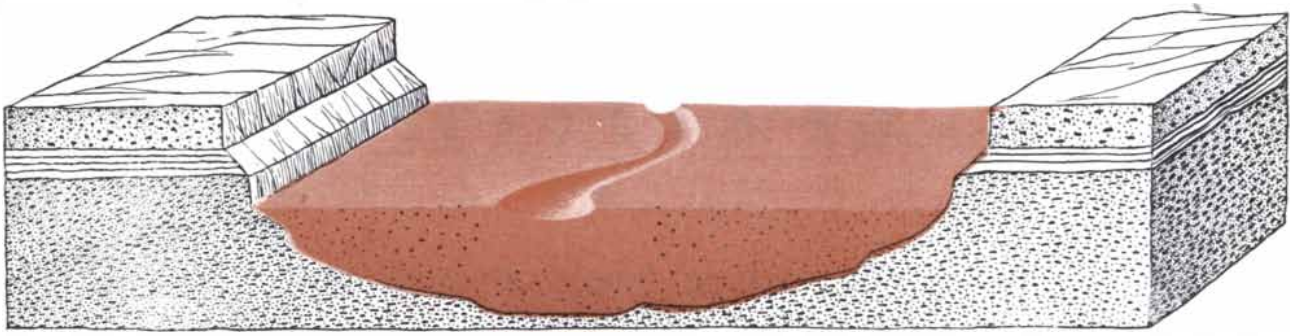
by Sheldon Judson

WHEN the Spanish explorers of America first came to the U. S. Southwest some 400 years ago, they found it a land of grassy meadows, green valleys and clear running streams. Today the once green valleys are arid and deeply gashed by dry, ugly gullies. What has caused this grim change in the landscape? Most people lay the blame upon man's misuse of the land. But recent investigations have given us a new and somewhat surprising view of the erosion story in the Southwest, and this article will piece together that story.

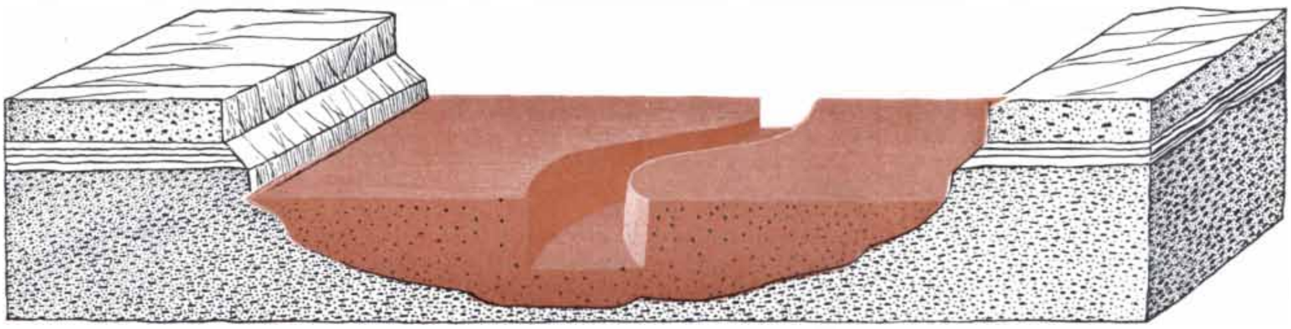
If you drive through New Mexico and Arizona on Highway 66, the *Grapes of Wrath* road, you will cross one after another of the destructive arroyos that have withered the Southwest. You can get a better view of these grim scars on the country if you leave the main highway, which spans them smoothly, and travel over the side roads. The arroyos are sheer-walled trenches cut 20 to 70 feet deep into the soft sand and silt of the terrain. Their blighting effects are many and various. Not only do they cut away grazing and farm land along their own channels but they drain soil moisture from the adjoining plain, so that its grass withers and dwindles. Furthermore, winds whip the loose sand from their dry beds and drift it over the surrounding country, smothering the vegetation. Nor are the effects merely local. The cloudbursts that are so characteristic of this region wash sand, silt and clay from the arroyo bottoms into the major rivers, which carry it to the lakes impounded by the Southwest's great dams. Year by year this freight of soil is slowly filling the lake basins, reducing their water-storage capacity.

The present arroyos have developed only within the last 65 years. Until about 1885 the country was still much as the Spanish settlers had found it: broad, flat, uneroded valleys with ex-

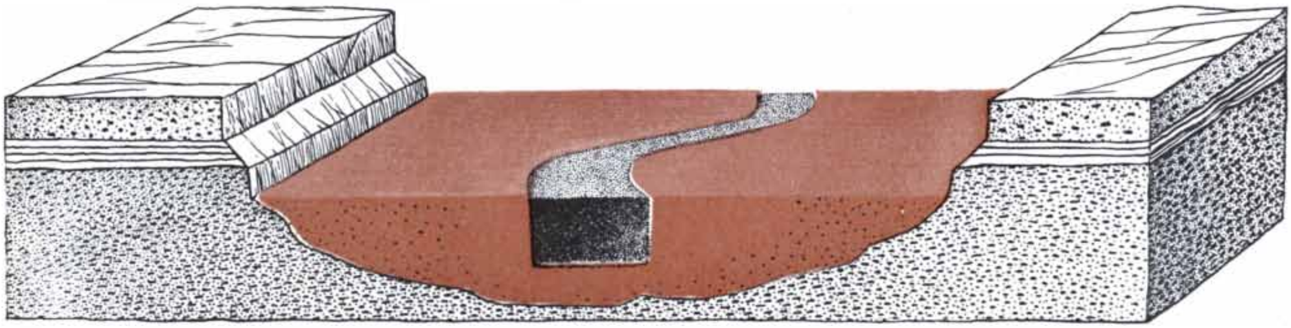
ARROYO called Chaco Canyon cuts across a valley in northwestern New Mexico. This photograph was made from the northern wall of the valley. At the lower right are the ruins of an Indian village called Pueblo Bonito.



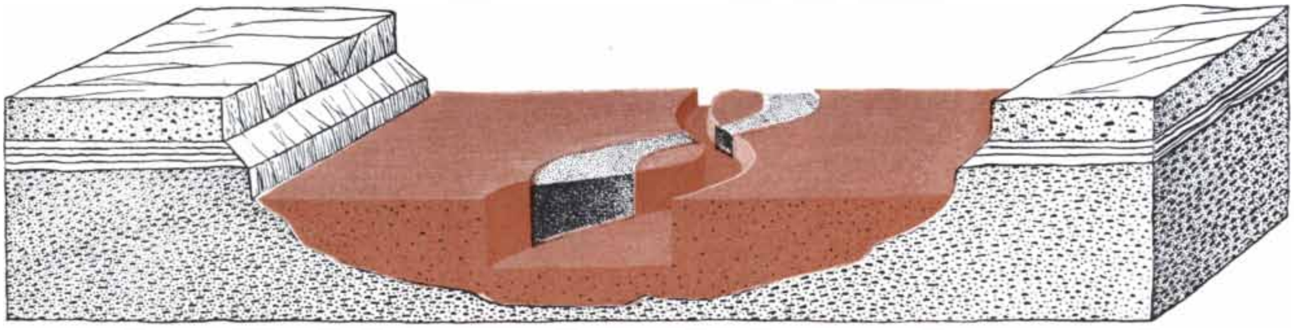
River carves a shallow channel on the floor of a valley filled with alluvium (brown).



Floods caused by loss of vegetation cut a deep, steep-walled arroyo in the path of the river.



Arroyo is filled with gray sediment when the vegetation returns and holds water on the slopes.



New loss of vegetation leads to second arroyo which cuts across the path of the first.

cellent grazing grass, flowing streams and long narrow pools of water called *charcos*. Then a wave of erosion swept up the alluvial valleys of the Southwest. Within a few years the streams had chewed out steep-walled channels in the soft earth. As time passed, these deep gullies widened.

What started this cycle of erosion was a weakening of the vegetative cover. In the Southwest the balance between protection and erosion of the soil is extremely delicate. When the vegetation begins to thin and leave bare patches, rains start stripping and washing the soil from the bare spots. Gradually these patches widen. The grass becomes too sparse to soak up rain. The rains of the Southwest are of a particularly destructive kind. Although the total annual rainfall is low, averaging no more than 10 inches in the least dry areas, it usually comes in downpours. During such cloudbursts the water collects in the valley bottoms and there, rushing along the lowest course, begins to cut arroyos. It starts by chewing out a small waterfall in the ground and then works the cut toward the valley head, each rain eating farther upstream. Many arroyos grew at the rate of a mile or more per year.

THE KEY question is: What started the weakening of the protective vegetative cover? The answer that first springs to mind is overgrazing. During the late 1800s optimistic herders ran vast numbers of cattle and sheep into the Southwest—far more than the vegetation could readily feed. And yet evidence piled up during recent years, beginning with the work of the late Kirk Bryan of Harvard University, indicates that this raid upon the vegetation was only a trigger force, setting off a process which had already been primed by natural causes.

The major factor apparently was a slight change in the pattern of rainfall in the Southwest. Records of precipitation in this region have been kept for about 100 years. During that period the total annual rainfall has not varied much. But Luna B. Leopold of the U. S. Geological Survey, after analyzing the records, recently turned up the significant fact that in the last half of the 19th century the Southwest's rainfall seems to have been made up of an unusually large proportion of heavy rains (over one inch) and an unusually small proportion of light ones. That is to say, the average number of heavy rains per year was larger in that half-century than it has been since 1900, and the number of light rains smaller. Now it is heavy rain that causes the greatest and most rapid erosion, while light rain helps build up the vegetative cover. Thus the rain pattern of the late 1800s tended to weaken the vegetation, and this situation, aggravated by overgrazing, seems to have been responsible for initiating the cycle of erosion.

We have now found support for this idea in the region's geologic past. If the theory is correct, we should expect to find evidence of previous cycles of erosion, associated with climatic fluctuations. And the walls of the arroyos, where old layers of deposits lie exposed, do indeed show such evidence. At least two and probably three cycles of erosion swept across the Southwest in the past and were later healed by fresh deposits washed over the valleys by resurgent streams.

In the vertical walls of the modern arroyos the generally reddish brown deposits of old river muds, which built up the valley floors, are laced here and there with long, sinuous channels of gray material. This is the alluvium that filled old arroyos cut into the red valley bottoms. Studies during the last 25 years have shown that this channel-cutting took place over a wide area, from Arizona to Western Texas.

LET US examine the most recent of these arroyos, which had been filled not long before the conquistadors came. From fragments of Indian pottery found there we can estimate that these arroyos were in existence A.D. 1300. This was about the time of large migrations of Indians in the Southwest, and their migrations may have been caused by the erosion. The pottery fragments suggest that the arroyos were cut after 1200 and filled in again by 1400 or shortly afterward.

As to the initiating cause of this erosion, several possibilities have been suggested, but the only one that can account for its wide extent is a climatic change. The area was sparsely populated, and the early Southwestern Indians had no domesticated animals, hence overgrazing or misuse of the land cannot be blamed. On the other hand, studies of tree rings by A. E. Douglass of the University of Arizona show that a great drought occurred in the Colorado plateau between 1276 and 1299. Furthermore, pottery has been found in sand dunes formed about that time. It is reasonable to suppose that the drought climaxed a long period of ineffective rainfall.

The "granddaddy" of all erosions in the Southwest took place several thousand years ago. It had been preceded by a moist period during which elephants, hickory trees and small lakes flourished in places where it would be difficult indeed for an elephant to make a living today. Then the streamways of the Southwest began to erode, and the erosion exceeded the gloomiest nightmares of modern soil conservationists. The arroyos were deeper and broader than anything later recorded, and the sand dune activity was much greater. When this erosion began, or how long

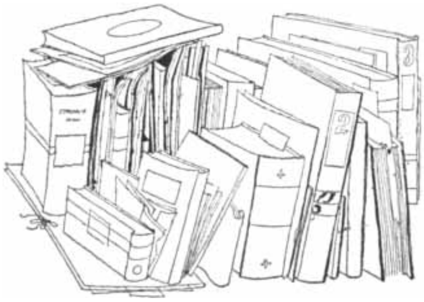
it lasted, we do not know. We do know that this was a warm "post glacial" period over the earth as a whole, and in the Southwest the higher temperatures must have spelled drought. The few dates available for this warm, dry period suggest that it climaxed about 6,000 years ago. The great erosion of the Southwest probably straddled this date and extended an unknown distance on either side of it. The Folsom and contemporary cultures did not survive the dry period, and the big game they hunted—mammoth, giant buffalo—never reappeared.

THUS the geological record establishes several facts. First, arroyo-cutting has happened again and again in the Southwest, and along the same streamways that are now gullied by deep channels. Second, all of the old erosions were healed by later deposits. Streams again flowed in the old channels and eventually blotted out the arroyos with their alluvium. And finally, there is much evidence that shifts in the climate were the basic cause of the erosion and alluviation cycle. These shifts in climate could have been very slight. In the Southwest it does not take much change in rainfall to initiate erosion. And as a corollary to this, very probably it does not take much shift in climate to start the recovery of vegetation and the refilling of the arroyos.

What, then, can we do about the modern erosion? We know that the old arroyos were filled up by nature, probably by a return of more effective precipitation. From this we can postulate that the present arroyos also will heal when the proper climatic conditions prevail. Must we wait for nature to do the job? It is a discouraging thought. Yet there seems no alternative. To date no other methods have proved practicable. An enlightened land policy will, of course, be important in preserving any gains made by nature. But it is extremely doubtful that even the strictest control of grazing, combined with "upstream engineering," will bring alluviation of the arroyos unless it is accompanied by sufficiently effective precipitation.

We seem, however, to be on the upswing of the climatic cycle, for according to the weather records the rainfall pattern has been improving during the past 50 years. Apparently the cycle of erosion and rehealing that occurred before the conquistadors came took about 200 years. Although recovery will be slow, nature with human aid should once more make the Southwest the green grassland that the Spaniards found four centuries ago.

Sheldon Judson is assistant professor of geology at the University of Wisconsin.



CHILDREN'S BOOKS

A third annual survey of writing about science for younger readers

by James R. Newman

THIS is my third annual roundup of children's science books, an exertion which has understandably given rise to some strong opinions about this branch of literature. Of the hundreds of books I have read, few have impressed me as first-rate. The majority range from mediocre to wretched; the wretched examples are not rare. I should like to set down a few general comments as to why, in my opinion, so many of them fail—not as an expert (I doubt that anyone except a child can truly claim authority in this field) but as a reader and a parent.

The first point concerns the not infrequent confusion about the age group to which a book is addressed. Educators often divide reading-age levels into the following four brackets: 5-7, 7-9, 9-12, 12-15. This is a loose grouping, but it is not unreasonable. If you have a young John Stuart Mill in your home, you may disregard it, but in general a child's taste, curiosity and powers of comprehension change as markedly from one age level to the next as his shoe size. One might suppose this to be painfully self-evident. Apparently it is not self-evident to many authors and publishers. Misleading blurbs by publishers are a nuisance, but by now bookbuyers may be assumed to have learned what horsebuyers have always known. On the other hand, a befuddled author is a menace. It is a serious matter to disappoint or frustrate the child who desires to know and who is willing to read and find out. The author who can't decide for whom he is writing should drop his pen; the chances are he neither understands his subject nor appreciates his responsibility to the reader. Nothing is more absurd, it seems to me, than to pretend that a book is suited to children ranging all the way from 10 to 15; yet at least two dozen volumes piled on the floor next to my desk claim to make this remarkable stride. The only kind of book that can span this age difference is a stamp album.

The second point, not unrelated to the first, is that many writers fail to distinguish between teaching scientific facts and scientific method. In general the child under 10, uncritical and hungry for information, is receptive mainly to facts—if they are stated clearly and are related to himself and to his intimate world. In an able paper on this subject written for UNESCO ("The Popularization of Science through Books for Children"), Amabel Williams-Ellis used the word "concentric" to describe this approach. The aim is to tie new facts to familiar things and thereby to enlarge the child's circle, to enrich his social as well as his scientific environment. Physiology is an example of a subject lending itself effectively to the concentric method of instruction; physics and chemistry are less adaptable to younger children. The essential axiom in this field, Mrs. Williams-Ellis points out, is that "the child must have nothing to unlearn." It is no boon to a child of 8 or 9 to share with him your wisdom about electricity, atomic energy or natural selection; eventually almost everything you teach him will have to be unlearned.

A child who has entered the stage where curiosity is tempered by skepticism is ready to be told about scientific method. He is equipped to learn how theories are put, how experiments are conducted, what constitutes scientific evidence and proof. At 12 to 15 years, he can be safely exposed to the facts of scientific life: the importance of doubting, the limits of scientific knowledge, the frustrations and difficulties of research, the fumbling, haphazard character of scientific advance.

This brings me to my third point. One of the best ways of making palatable the essentials of scientific method is to embed them in a biography. This form of exposition is unusually flexible; its dramatic and dynamic elements, skillfully handled, can make the learning of science vivid and memorable. However, the biographies I have read are, with occasional exceptions, the least satisfactory of science popularizations. The portrait of the hero is usually two-dimensional: he is poor, virtuous, dedicated, clever and kind to his parents. His scientific career is a blend of good fortune and brilliant inspiration. ("One day he happened to be turning the handle of the generator when he suddenly noticed . . ." "Suddenly the reason for the strange behavior of the solution in the beaker was revealed to him. . . .") This sort of thing is all very well for motion pictures of the life of Pasteur or Edison; it is not very well for the education of those who are still capable of being educated.

Children's books are handsomer, if more expensive, than they were a few years ago. Yet I observe that authors now often transfer to the illustrator the main responsibility for the story. This is a mistake. Regardless of the excellence of the pictures the burden of presentation must be on the text. Science books should be read, not merely gazed at. Pictures can give invaluable support; but they should not be called upon to fill gaps in the story or to explain what the author lacks the wit to explain.

Science popularization for children, I am sorry to note, receives less regard from educators than it deserves, less effort from writers than it requires, less attention from publishers than its potentialities justify. The 50-odd children's science books here reviewed represent a substantial part of this year's publications in the field; compare this with the annual outpouring of perhaps 10 times as much children's fiction and miscellaneous juveniles—most of it third-rate. A melancholy contrast.

Happily there are books on the science list that can stand as models for authors and publishers. I am glad to report that at least half a dozen of the items that follow have exceptional merit.

Physical Sciences

THE ELECTRIC CURRENT, by P. Dunsheath. G. Bell and Sons, Ltd. ($2.60). This collection of the Royal Institution Christmas Lectures of 1949 traces the history of ideas about electricity and explains for boys and girls (12 and older) the modern theories and applications of electric current. Mr. Dunsheath, a leading British electrical engineer, is a fluent and lucid lecturer and he has taken into consideration that the reader is not privileged, as was the lecture audience, to witness the many vivid demonstrations that feature the talks in this famous series. Clear diagrams and plates help to make this an excellent book.

THE SECRET OF LIGHT, by Irving Adler. International Publishers ($2.25). This book, written for high school ages, covers a lot of ground, some stretches at a comfortable pace, some too fast. Mr. Adler begins by explaining mirrors and lenses and the essentials of light behavior, and then carries the reader forward steadily through X-rays, other forms of electromagnetism, the structure of the atom, quantum mechanics and relativity. The author, head of a high-school mathematics department, has a thorough grasp of the subject and a considerable gift for popularization, especially of the more difficult branches of the subject. His chapters on atomic structure and on the Bohr model of the atom, for example, are first rate. The drawings by Ida Weisburd are adequate.

Stepping Stones to Light, by Richard W. Bishop. Thomas Y. Crowell Company ($2.50). An anecdotal history for children of 10 and older of the discoveries and inventions culminating in Edison's electric light. Short chapters describe the work of Gilbert, von Guericke, Ohm, Coulomb, Ampère, Oersted, Faraday, Davy, Galvani and others. There is a brief bibliography.

Experiments in Optical Illusion, by Nelson F. Beeler and Franklyn M. Branley. Thomas Y. Crowell Company ($2.00). Optical illusions have many causes. They result from the peculiar structure of the eye, from the color of perceived objects or their motion, from psychological patterns, from the circumstance that we use two eyes for seeing, from combinations of these and other factors. In this book for 12 to 15s the authors, who have collaborated on similar primers, gather numerous examples of how our eyes may trick us. Many of the illusions are amusing, though familiar; some require setting up easy apparatus. Mildly instructive.

Sound: An Experiment Book, by Marian E. Baer. Holiday House ($2.50). A large number of simple experiments demonstrating that sound is vibration, that it travels, can be amplified, is reflected, and so on. Children from 9 to 12 with an interest in general science can profit from these basic exercises and will have fun doing them.

Lightning and Thunder, by Herbert S. Zim. William Morrow & Company ($2.00). Perhaps this book was written too fast even for the prolific Dr. Zim; at any rate it is less informative than other books he has published, and manages to leave out facts which even a primer ought not neglect. Thus 8 to 12s will not learn from this book that a lightning flash consists not only of a downward thrust but also of a high-voltage streamer from the earth rushing up to meet it. The fact is one children can live without, but not if they wish to know about lightning.

Sun, Moon, and Planets, by Roy K. Marshall. Henry Holt and Company ($2.50). A short, informal survey of astronomy for high-school children, intended to answer oft-repeated questions about the sky. The author was formerly director of the Fels Planetarium in Philadelphia and the Morehead Planetarium in Chapel Hill and has conducted science programs over radio and television. Dr. Marshall is a gummy expositor.

The Atmosphere, by Peter Hood. Oxford University Press ($2.50). Second of a series of annotated picture books, for ages 12 to 15, dealing with the physical and natural sciences. Excellent illustrations and a lucid text convey considerable information on such matters as the ionosphere, the reflection of radio and sound waves, how clouds are formed, the machinery of rainfall, fog, snow, hail, measuring wind and barometric pressure, the causes of cyclones, aurorae, rainbows, methods of weather forecasting and so on.

Experiments in Chemistry, by Nelson Beeler and Franklyn Branley. Thomas Y. Crowell Company ($2.50). A kitchen-and-cellar research manual giving directions for experiments. It shows, among other things, how crystals are formed, the use of salt as an electrolyte, the manufacture of ink (with tacks and tea), the making and testing of starch, the causes and prevention of corrosion, the action of detergents, the chemical behavior of paints, fats, plaster of Paris, enzymes, silicones. For ages 11 to 14.

Rocks, Rivers and the Changing Earth, by Herman and Nina Schneider. William R. Scott, Inc. ($3.00). A first book about geology for 10-year-olds and older, handled with skill and sensitivity. The Schneiders tell in simple language how the land is worn down by wind and water, how rivers and lakes are made, how the sea is filled in, how the land is built up, how we and every particle of matter from sand grain to mountain, raindrop to glacier are part of this never-ending cycle. Illustrations by Edwin Herron.

Biological Sciences

All About Eggs and How They Change into Animals, by Millicent Selsam. William R. Scott, Inc. ($2.00). Miss Selsam tackles familiar themes better than anyone else around. Gentleness, delicacy of understanding and exceptional clarity characterize all her primers on plant and animal life. This little book on the ABC of embryology, illustrated by Helen Ludwig, is for 6 to 9s.

The Wonderful Egg, by G. Warren Schloat, Jr. Charles Scribner's Sons ($2.25). Large, clear photographs tell the child how a hen lays its eggs, how they grow, how a chick eats its way out of the egg, how incubators work, and—a matter of no slight importance—how to make a "Gold Mine" egg sandwich. This is a simple and effective book for youngsters of 5 to 8 who are starting to ask questions about the beginning of life.

Birds and Their Nests, by Olive L. Earle. William Morrow & Company ($2.00). The variety of birds' nests is astounding. Bald eagles build nests high up, open to the sky and of enormous size, sometimes 20 feet deep and 9 feet across. Flamingoes make compact mounds of mud at the edge of a marsh or swamp and place their eggs on the top, which is hollowed to form a shallow cup. The horned owl makes a large untidy nest, and the American redstart makes a beautiful little bowl lined with dandelion down, fine grass and hair, lashed with spider's webs. The ovenbird makes a home shaped like an old-fashioned oven. The magpie builds its nursery entirely under cover. The South African weaverbird builds a hanging home which resembles an African native's thatched hut. The red-eyed vireo suspends what appears to be a cave man's club from the horizontal fork of a tree. The elf owl lives in a tree hole made by a Gila woodpecker, which itself lives in the trunk of the giant cactus. A delightful, well-illustrated book for children of 10 and up.

Trees of the Countryside, by Margaret McKenny. Alfred A. Knopf ($2.75). Descriptions of some 29 common American trees, with brief notes about their leaves, blossoms, fruits, seeds and the use made of their wood. Attractive four-color lithographs by Alice Bird. A graceful little book for teen-agers.

Let's Go to the Brook, by Harriet E. Huntington. Doubleday & Company, Inc. ($2.75). About the plants and small animals—beetles, snails, crayfish, damsel flies, nymphs, toads, worms and fish—found in and around a country brook. Miss Huntington supplements her brief text, intended for 6 to 9s, with photographs, some of which are quite good but are here indifferently reproduced by offset lithography.

The Wonder World of Animals, by Marie Neurath. Lothrop, Lee & Shepard ($1.50). How animals fight, feed, care for their young, build homes, work together. A shopworn idea, but Miss Neurath, with the help of gay pictures and an unaffected text, carries it off nicely. For 8-year-olds.

What's Inside of Plants, by Herbert S. Zim. William Morrow & Co. ($1.75). Dr. Zim's book about seeds, flowers, fruits, roots is presented on three levels. Vivid colored pictures by Herschel Wartik are meaningful for children below reading age, and amplify the story generally; there are large-type pages, which can be read by children of 7 or 8, and small-type pages, whose more detailed text is intended "to be read by an adult while a child looks at the pictures." The product is a little confusing, but the information is accurate and abounds in interesting facts: *e.g.*, a single rye-grass plant has 14 million roots which, put end to end, would extend for hundreds of miles.

What's Inside of Me, by Herbert S. Zim. William Morrow & Co. ($1.75). This book follows the method used in Dr. Zim's story of plants but comes off better. It describes the principal organs of the body and their functions. For children of 5 to 8—with parents' help. A simple text and large colored illustrations by Herschel Wartik.

Thanks To Trees, by Irma E. Webber. William R. Scott, Inc. ($2.00). For 9 to 12s a straightforward story of how trees live, help store water in the ground, enrich the soil and provide valuable foods and other products that serve men's needs. It also stresses the devastating effect of cutting too many trees and the importance of forest conservation. Good pictures; a good book.

Alligators and Crocodiles, by Herbert S. Zim. William Morrow & Co. ($2.00). Alligators are rarely over 10 feet long, live about 20 years (sometimes 40 under the benign conditions of the zoo), swim faster than two men can paddle a canoe, hardly ever eat people, are protected by conservation laws, take good care of their young, spend most of their time lying perfectly still and are able to bark, roar and bellow. Crocodiles have narrower and more pointed heads, are quicker, more aggressive and *do* eat people when given the chance. Dr. Zim gives the facts for ages 9 to 12. Illustrated by James Gordon Irving.

Garden Spider, by Mary Adrian. Holiday House ($2.00). The life cycle of a garden spider from the time she lays her 500 eggs (in 10 minutes) to the time when one of her daughters, having grown up, spins her beautiful nest, catches a few insects, mates, eats her husband and, having thus passed a pleasant summer, is about to repeat her mother's performance. For 6 to 9s.

Play with Leaves and Flowers, by Millicent E. Selsam. William Morrow & Co. ($2.00). About leaves, fruits and seeds that move; leaves and plants that sleep and catch insects; flowers that give off a gas and others that are set on little swivel joints (called "obedient plants"); how to grow and observe these plants; where their seeds can be bought or found. A charming book for children from 9 to 12, describing experiments they can do themselves. Pictures by Fred F. Scherer.

Honeybee, by Mary Adrian. Holiday House ($2.00). Biography of a worker bee, describing how it was fed 1,000 times a day by a nurse bee; how it learned to feed itself in the hive and to gather nectar; how it made wax, cooled the hive by beating its wings, learned to communicate by means of the "round dance" and the "wagging dance"; how it burned itself out in six weeks working harder than a child laborer in a 19th-century British factory. For ages 6 to 9.

Go with the Sun, by Miriam Schlein. William R. Scott, Inc. ($2.00). What happens to various animals—birds, fish, insects, mammals—during the winter months, is explained for children 4 to 7. The text is half whimsy and half treacle, but the illustrations by Symeon Shimin are appealing.

Grass: Our Greatest Crop, by Sarah R. Riedman. Thomas Nelson & Sons ($3.00). Where and how grass grows (there are 1,000 species in the U. S. alone), its uses in soil and water conservation, its enemies, its direct and indirect contribution to the world's food supply. An informative book—not too lively—for youngsters under 14. Illustrations.

Prehistoric America, by Anne Terry White. Random House ($1.50). For boys and girls of 10 and older the story of the biological and geological evolution of the North American continent. Miss White tells of the growth of mountains, lakes and rivers, the effects of the ice ages, the animals that inhabited the country during various epochs, the reconstruction of the past by paleontological and archaeological research. The style is breathless but the narrative keeps moving and is easy to follow; the one serious defect is that Miss White couches her explanation of evolution in such naively purposive terms that children who read her book will have a hard time grasping the fact that biological adaptation does not consist of conscious and directed effort by the species to grow long necks so as to reach bananas on high trees or develop sharp teeth to chew up the enemy.

Social Sciences

Water For People, by Sarah R. Riedman; Planet Earth, by Rose Wyler; The City, by Rod and Lisa Peattie. Henry Schuman ($2.50 each). These three books introduce a new series ("Man and His World") addressed to ages 10 to 15. The age grouping is awkward for science primers, and the authors appear at times to be unclear for whom they are writing. For example, Dr. Riedman, giving directions on how to perform a certain experiment, first uses the word "desiccator" and then follows with: "Ask your mother if you may use the oven. Be careful not to burn yourself." A child of 10, not to mention 15, who needs these instructions shouldn't be trusted with a book, let alone an oven. Apart from the sad consequences of trying to write for elementary, junior and high school children all at the same time, two of the volumes are above average in conception and execution. Miss Riedman's book is pedestrian and covers a subject which has been more ably handled by other writers, but a child can get reliable information from her story of the properties and uses of water. Miss Wyler writes knowledgeably about weather, food resources, discovery and exploration, astronomy, population, water supply—a potpourri upon which the author has nevertheless conferred a certain plausible unity. The Peattie book is an exceptional achievement. It deals with the curious way that cities grow—spreading in a rough circle from some important place such as a bridge or a harbor, "pushing out branches like feelers"—and with the good and evil effects cities have had, and continue to have, upon men's ways of thinking, upon their social, political and economic habits. The theme is original, the writing superior and the illustrations (by Bunji Tagawa) are exemplary.

THE LEWIS AND CLARK EXPEDITION, by Richard L. Neuberger. Random House ($1.50). Mr. Neuberger is a student of the Pacific Northwest and has written prolifically on the history, politics, social and economic problems of the region. This is a well-paced, exciting and authoritative story of the great adventure of Captain William Clark and President Jefferson's private secretary, Captain Meriwether Lewis, in leading 33 men up the Missouri, across the Rockies, down the Snake and Columbia rivers to the Pacific. Pictures and map by Winold Reiss. Recommended.

THE VIKINGS, by Elizabeth Janeway. Random House ($1.50). One of the praiseworthy "Landmark Series," this is a fictionalized account of Leif Ericson's voyage from Greenland to America, and of his brother's later visit to Cape Cod, Connecticut, Rhode Island and other points further south on the coast—places not so well known in the 10th century, or so heavily traveled, as they are today. Unconvincing and slightly mechanical, but harmless.

THE FIRST BOOK OF ESKIMOS, by Benjamin Brewster. Franklin Watts, Inc. ($1.75). The latest addition to a popular series, this book offers an agreeable combination of text and pictures (by Ursula Koering) dealing with the Eskimos' daily life. It describes their clothing, home-building, cooking, hunting; how they catch whales with weapons made of only a few pieces of wood, bone and hide; their invention of snow goggles and of skin boots for their dogs; their social habits; how contact with other peoples has affected their lives. Children will like this book well enough to want more information on the subject—a dependable test of merit. For ages 7 to 10.

PICTURE MAP GEOGRAPHY OF AFRICA, by Vernon Quinn. J. B. Lippincott Company ($2.75). A miscellany of facts about the several countries and regions of Africa, supported by maps with pictures and symbols portraying animal life, resources, living habits and other notable features. It is the seventh of these books by Miss Quinn and neither better nor worse than its predecessors—which is to say, mediocre. For ages 9 to 12.

THE GOLDEN GEOGRAPHY, by Elsa Jane Werner. Simon & Schuster, Inc. ($3.95). Youngsters of 10 and older will find this an excellent introduction to geography and will profit from it as from few of their textbooks on the subject. It is written with an intelligent appreciation both of the range of the child's curiosity and of his capacity to assimilate new and strange information. The pictures by Cornelius De Witt are as colorful as tin soldiers and richly instructive. A delightful primer recommended for school and home libraries; books of this kind turn a fresh page in education.

THE STORY OF THE TOTEM POLE, by Ruth Brindze. The Vanguard Press, Inc. ($2.75). A well told, superbly illustrated story of the origin, meaning and uses of the totem pole by an author who has written two other excellent books for boys and girls, *The Gulf Stream* and *The Story of Our Calendar*. Miss Brindze describes the remarkable art of carving history and legends on giant red cedars as practiced by the Indians of our Northwest Coast. A fascinating and beautiful book for age 8 or older. Color pictures by Yeffe Kimball.

THE FIRST BOOK OF AIRPLANES, by Jeanne Bendick. Franklin Watts, Inc. ($1.75). Snippets of information on how planes fly, the kinds of aircraft and their engines, the operation of commercial and military planes, what pilots need to know about weather, navigation, safety rules and so on. Miss Bendick seems to be on unfamiliar ground. The book is below her standard, both as to text and illustrations.

THE BIG BOOK OF REAL AIRPLANES, by Charles L. Black. Illustrated by George J. Zaffo. Grosset & Dunlap ($1.00). Missiles, jets, rockets, helicopters, warplanes. The text is thin and not too plain, but the illustrations are almost as satisfying as a fire engine.

ROCKETS AND JETS, by Marie Neurath. Lothrop, Lee & Shepard ($1.50).

ROCKETS, JETS, GUIDED MISSILES AND SPACE SHIPS, by Jack Coggins and Fletcher Pratt. Random House ($1.00). These two books are better than average introductions to a fascinating subject. Miss Neurath uses bright, simple illustrations to explain the rocket and jet engine principle for children of 10 to 12. Coggins and Pratt offer for a somewhat older age group an interesting account of the history and development of these fateful gadgets. Their book describes the tightly packed, powder-filled paper tubes used in the 13th century by the Chinese to frighten off the Mongolian invaders, the Congreve rockets the British lobbed into Baltimore in 1814—which made more of an impression on Francis Scott Key than on the target—the amazing advances in the military use of rockets and other missiles during the last war, recent research in jet and rocket flight, the giant step-rockets now being planned for a first assault on the moon. An agreeable introductory survey for anyone over 12.

MODEL JETS AND ROCKETS FOR BOYS, by Raymond F. Yates. Harper & Brothers ($2.50). Mr. Yates gives a brief history of rockets, and then devotes several chapters to detailed instructions on how to build jet propelled aircraft, racing cars and boats, using ordinary household items and a few gadgets that can be purchased inexpensively. A complete jet engine that will run a model plane at 200 miles per hour costs only $1.95; fuel tanks can be made out of empty 35-millimeter film containers. The text is helpful, but some of the diagrams will bewilder the boy who isn't an accomplished model maker.

PICTURE BOOK OF RADIO AND TELEVISION AND HOW THEY WORK by Jerome S. Meyer. Lothrop, Lee & Shepard ($2.00). The elements of radio and television, with an account of some of the other inventions that led the way. The exposition is uneven: clear in some points, and incomprehensible, except possibly for an expert, in others. Illustrations by Richard Floethe. For ages 11 to 14.

GIFTS FROM THE FOREST, by Gertrude Wallace Wall. Charles Scribner's Sons ($2.50). How great trees are felled, bucked, scaled, loaded on huge trucks, carried to the mill, unloaded at the millpond, washed, sawed by crosscut, converted into boards, graded and distributed. A simple, accurate story. Large, clear photographs by John Calvin Towsley. For children over 8.

YOUNG PEOPLE'S BOOK OF RADAR, by Lt. Commander David C. Holmes, U.S.N. The McBride Company, Inc. ($2.95). An enlightening introduction for teen-agers. Holmes tells how radar works, its uses in peace and war, the inventions that gave rise to it and its possible future applications in research, technology, transportation, industry, exploration of interplanetary space.

YOUR TELEPHONE: AND HOW IT WORKS, by Herman and Nina Schneider. Whittlesey House, McGraw-Hill Book Company, Inc. ($2.00). The working of the telephone: how the manual and the dial systems operate, the essentials of radiotelephony and radio. This is unquestionably the best book of its kind. laying a sound basis of understanding for later school work in physics and elementary science. Ingenious illustrations by Jeanne Bendick. Highly recommended for children of 10 and up and for parents and teachers.

OARS, SAILS AND STEAM, by Edwin Tunis. The World Publishing Company ($3.50). A handsome picture book portraying the evolution of ships from primitive man's hollowed-out log to the latest Guppy Type Snorkel Submarine—representing a technical if not a cultural advance. Mr. Tunis draws sharp, clean-looking pictures of each leading type of vessel and provides a running commentary of historical and nautical detail. A glossary is added, defining the principal nautical terms.

IT'S FUN TO KNOW WHY, by Julius Schwartz. Whittlesey House, McGraw-Hill Book Company, Inc. ($2.25). Experiments for 9 to 12s with simple things—iron, coal, glass, rubber, soap, salt, bread, paper—to show how they are made and used. Mr. Schwartz is an experienced science teacher and this is an intelligently planned book which even children without a knack for tinkering can enjoy and learn from.

THE PANAMA CANAL, by Bob Considine. Random House ($1.50). A history of the Canal, of the men who failed and of those who finally succeeded in cutting the big ditch across the Isthmus. Mr. Considine gives a lively journalistic account of the scandals and difficulties of the great project, but his description of the engineering and health problems, an equally dramatic story, is skimpy.

Biography

SIGMUND FREUD, by Rachel Baker. Julian Messner, Inc. ($2.75). A devout biography of the founder of psychoanalysis, stereotyped in its portrait of the man but interesting in its description of the evolution of Freud's ideas and of the disputes among his early disciples. Miss Baker is to be admired for attempting to make Freud's theories accessible to "young people." Unfortunately she seems not to have been able to make up her mind for what age group her story was intended; sometimes her book is for 12-year-olds but at other times it is only for 12-year-olds who have entered medical school.

Modern American Engineers, by Edna Yost. J. B. Lippincott Company ($2.50). Sketches of 12 successful engineers—mining, electrical, television, automotive, civil, mechanical, agricultural, petroleum. Miss Yost means well, but it is hard to believe that even engineers' lives can be as dull as those here described.

Famous Men of Science, by William Oliver Stevens. Dodd, Mead & Company ($2.50). Seventeen short biographies of such leaders as Copernicus, Galileo, Newton, Lamarck, Faraday, Lyell, Darwin, Mendel. An uninspired book, obviously written to formula, conveying the minimum scientific information. Each sketch is like a Hollywood version of a great inventor's life.

Famous Naturalists, by Lorus J. and Margery J. Milne. Dodd, Mead & Company ($2.50). A plodding series of sketches of 14 naturalists, including van Leeuwenhoek, Gilbert White, Darwin, Wallace, Thoreau, Audubon, Fabre and Burroughs. This book is addressed to children between 10 and 14 and is bound to drive them out of doors for some other form of entertainment.

Men Who Changed the World, by Egon Larsen. Roy Publishers ($3.00). Stories of invention and discovery for young people of high-school age. Mr. Larsen writes in a lively way about Alexander Graham Bell, Thomas Edison, Henry Ford, the Wright Brothers and a few inventors less well known in this country: John L. Baird (television), Sir Frank Whittle (jet propulsion), Sir Robert Watson-Watt (radar), William Friese-Greene (motion pictures). The only pure scientist included is Lord Rutherford. It is not a book from which much can be learned about how inventions or discoveries are made, or how scientists pursue their researches, but it is good entertainment and certain to inspire the young, assuming the young can be inspired this way.

Leonardo Da Vinci, by Elizabeth Ripley. Oxford University Press ($3.00). A short, simple, honest biography of Leonardo, with 30 reproductions of his drawings and paintings, one facing each page of text. Among the illustrations are Leonardo's caricatures; his *Adoration of the Magi,* sketches of military vehicles; a design for underground streets in Milan; *The Last Supper;* sketches for an oil lamp, a self-turning spit, a diver's mask and a breathing tube; wings of a flying machine and helicopter; anatomical drawings; plant studies, and of course the *Mona Lisa.* This is one of the most beautiful books for children of 10 and up to appear in years.

THE AMATEUR SCIENTIST

On mouse genetics and a variety of things of interest to the avocational astronomer

Conducted by Albert G. Ingalls

FOUR years ago, when Marita Mullan of Philadelphia, Pa., was 15 years old, a boy who knew she liked animals gave her a pair of common house mice. The joke backfired. Her growing enthusiasm for the new pets soon left little time for him. She started haunting the public library and registered for special courses at the University of Pennsylvania, though she was too young to receive credit. Within a little more than two years she was invited to address the scientific staff of the Jackson Memorial Laboratory in Bar Harbor, Me. With the help of her mice, Miss Mullan had become an advanced amateur geneticist.

Miss Mullan's interest in genetics was sparked by a chance observation. One morning, when she went to the basement to water her mice, she made a strange and, as she learned later, rare discovery. A few days earlier the mice had produced a litter of six young, all pink and hairless. Now they were growing coats. This morning she noticed that one of the baby mice was not a mousy gray, like its parents, but bright orange! In the course of searching for the answer she bred mice of many colors and learned why the average householder is unlikely ever to trap an orange one.

She began with a review of the work of genetics' most celebrated amateur: the Austrian monk Gregor Johann Mendel. Mendel also started with a question. What factor, he wondered, relates true-breeding varieties within a species? For the answer he put the question directly to nature. He had had no previous training in science and so was forced to discover its method for himself: he stated his problem, experimented, observed, theorized, validated his theory by further experiment and finally expressed his findings as a set of natural laws.

Although Mendel worked with peas, his basic laws of heredity hold equally for mice, oak trees or men—for any organism that reproduces sexually. He cultivated and crossbred two varieties of peas—tall and dwarf. When the offspring of these matured, he was surprised to observe they had all grown tall, like one of the parents, instead of medium-sized, as he had expected. He then interbred these tall hybrids. Again he was surprised. This time the offspring were both dwarf and tall—and in the precise ratio of three tall plants to one dwarf.

What set of circumstances, Mendel wondered, would produce the orderly result he had observed? After much pondering he finally hit upon a theory that goes like this: Suppose the cells of the parent plants each contain a pair of factors in the form, for instance, of minute particles. One kind of particle can cause a plant to grow tall and the other dwarf. Suppose further that when the male germ cell of one plant unites with the female germ cell of the other, each contributes only one member of its pair of particles to the seed. The factor from this male parent, let us say, is invariably of the type causing tallness, and from the female, dwarfism. Then all members of the first hybrid generation from this pair of parents would get a tallness factor from the "father" and a dwarfism from the "mother." Assume that the tallness factor is dominant. Then all the offspring would grow tall.

But when these hybrids interbred in turn, a different result would be expected. The inheritance could now be mixed in four different combinations: tallness plus tallness, tallness plus dwarfism, dwarfism plus tallness, dwarfism plus dwarfism. The first three of these combinations would produce a tall plant, the last a dwarf plant. So on the average three out of four of the second generation should be tall.

It was a clever explanation—but did it really describe nature? Mendel tested it statistically on various hereditary characteristics of peas—the shape and color of the pods, the position of the flowers, the length of the stems and the texture of the seeds—and found that in every experiment his theory accurately predicted the results.

Today Mendel's mysterious factors are called genes. They are considered "atoms" of heredity—minute bits which may be studied only indirectly, by their effects, because they are too small to be seen even under the electron microscope.

Every organism begins life as a single cell. The genes are found in the cell's nucleus, arranged in threads or filaments like strings of beads. The threads are called chromosomes, from the fact that they can be stained with colored dyes for observation under the microscope. When a cell prepares to divide, the barely visible chromosomes gradually thicken and finally split down their length, each of the many genes in each new piece being duplicated in the other. Thus each of the daughter cells inherits a duplicate set of chromosomes and genes.

In all of nature the gene is the only known structure with the power to manufacture an exact copy of itself. But this does not mean that a gene cannot be changed. Every now and again some force acts on one gene or another and alters it. X-rays will do this. So will cosmic rays, various chemicals, extremes of temperature and other influences. Unless the affected gene is destroyed in the process, it will subsequently go right on making copies of itself—in its new, altered form. Such modified genes are called mutants. They account not only for the varieties within the species but also provide the basis for the origin of new species through natural selection. Some mutations are beneficial to the organism's chances of survival, but most are harmful. Fortunately most of the desirable ones are dominant and hence assist the development of useful traits. In contrast, recessive genes carrying a potential of undesirable characteristics can express themselves only when chance happens to pair them with like recessives in an offspring. In a large population the chances of such a meeting are small. Hence many generations may come and go before the unfortunate trait appears.

Marita Mullan's orange mouse represented such a rare event. The gene responsible for the trait is known as a "lethal yellow." As the name implies, this gene carries other changes more serious than the orange color. Lethal yellow mice die before they are old enough to mate. Miss Mullan's orange mouse died within a few weeks.

Such lethal mutants appear in all species. Fox breeders, for example, cultivate a highly prized variety of "platinum" fox. When platinum foxes mate, the hybrid is a snowy white. Like orange mice they never survive. Several lethal genes are carried by man, and science has learned how to circumvent the effects of some. Diabetes is genetic in origin; it is due to a defect or absence of the gene responsible for the manufacture of insulin. This genetic failure must be offset by administering insulin artificially.

The treatment of diabetes provides a clue to the nature of the chemical mechanism through which genes express themselves. The genes apparently govern the complex chemistry of cells, each gene being responsible for the cell's ability to manufacture a particular chemical link. This means that a great number of different kinds of chemicals must bathe the center of the cell, because complex organisms such as mice and men exhibit thousands of different traits, each accounted for by its own unique gene and corresponding chemical substance. It follows also that in this conglomerate chemical stew all the genes must to some extent modify one another's effects. Few genes, if any, act in complete independence.

In view of the interaction of the genes, it is logical to suppose that their position on the chromosomes could play a major role in shaping inherited traits. This is indeed the case, and it accounts for another mechanism by means of which varieties arise within a species. Sometimes when the new cell makes its initial division, the chromosomes break and grow together again in a different order, or several may break and exchange sections during reassembly. Short lengths, together with their complement of genes, may even be lost in the process. Any of these and related chance happenings may result in an offspring which carries a genetic structure differing from that of the parents. Hence, the offspring may possess a set of characteristics strange to the lineage—some visible and others obscure.

After a time, particularly in large populations where individuals mate outside the family line, the most dominant traits emerge. All individuals within the species bear marked superficial resemblance to one another, although the genetic systems of the mating partners may carry hundreds, even thousands, of contrasting and hidden recessives. Many of the recessives may be endowed with potential control over some one trait, such as hair color, but may never express themselves until they become paired with others of like kind through chance mating. Thus variation in many traits is subject to the control of a whole group of genes.

It was with such a group that Marita Mullan worked. She writes:

"Little did I realize the storehouse of potential beauty that my original pair of mice were hiding in the form of recessive mutants. Gradually, however, many of these varieties appeared in the offspring. Most of them are well known. Some were described long before the time of Christ by the Chinese, who bred these animals because of their singular beauty. Several unlisted traits came to light during my experiments.

"The most treasured of all fancy genes, and the most beautiful, is the pink-eye dilution. This gene somewhat reduces the amount of pigment in the skin and eyes. It also tends to produce a smaller mouse. The maltese or blue dilution is another mutant that tends to reduce the amount of pigment, but less drastically than the pink-eye gene. Black and brown is another striking combination and produces a blue-grey coat and a very beautiful chocolate color.

"The basic colors of the mouse's fur are produced by what is called the agouti series. 'Agouti' means that the fur has a characteristic variegated appearance, caused by the fact that each hair has a light and dark portion. It accounts for the typical mousy appearance of the wild mouse's fur. The series also contains the light-bellied agouti, the black-and-tan and the so-called non-agouti or black."

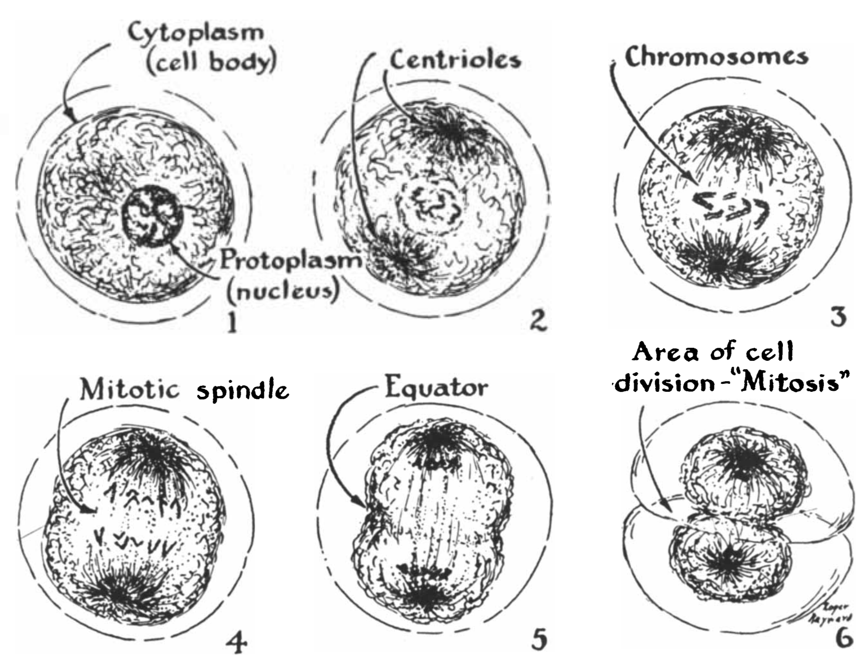
The work of a geneticist differs from that of a person who simply breeds animals or plants. In the first place, the geneticist hopes to learn more about the mechanism of heredity and, if possible, about the scientific basis of life itself. In the second place, the geneticist's breeding technique is guided by tested and proved laws, while the breeder generally proceeds on the rule of thumb that "like produces like."

Breeding by this classical method has gradually improved the stock of many plants and animals. By selective mating of individuals exhibiting the desired traits, man has developed products ranging from rust-resistant wheat to race horses. But after a time this method reaches a limit: no amount of careful selection seems to make any additional improvement. The quality of the stock levels off.

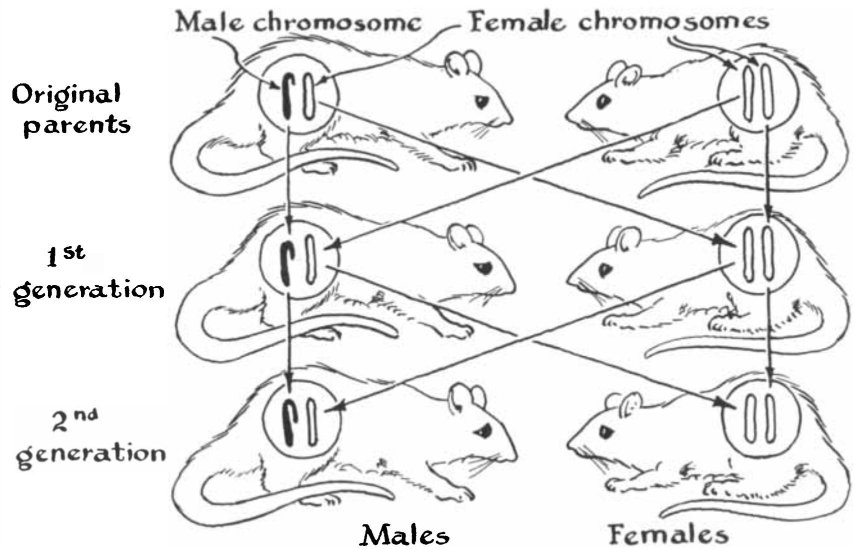
Genetics can do much better. At the turn of the present century Midwestern farmers were content with a strain of corn, for example, which yielded about 25 bushels per acre on the average. Today hybrid corn, developed by scientific application of principles of genetics, produces yields exceeding 200 bushels per acre!

How does genetics achieve such sensational improvement? Primarily by close inbreeding to establish desired traits and then the crossing of two unrelated inbred strains. Generally the product of this cross shows amazing qualities, far surpassing those of the immediate parents and of the ancestors on each side. Geneticists call the effect "hybrid vigor."

These and related principles guided the work of Marita Mullan. From her original pair of wild mice she developed dozens of independent strains. She kept careful records of each individual and,



CELL DIVISION begins when chromosomes divide and are pulled apart by filaments extending from the centrioles. The process ends when the cell splits into two daughter cells, which then mature and repeat the whole cycle.



SEX OF MOUSE is determined by one pair of chromosomes. The hooked black chromosomes in this diagram bear dominant factors for maleness. The straight white chromosomes bear recessive factors for femaleness.

following the example of Mendel, made tables showing the number of individuals in each generation with like characteristics. Her tables were far more complex than those listing the two factors of tallness and dwarfism in peas, however, because the several colors in mice are determined not by two genes but by a series. This vastly increases the number of possible combinations and adds to the interest and challenge of the game.

As Miss Mullan says, "The thrill of breeding unusual offspring is not the only appeal of genetics. Those who have crossword-puzzle minds will find that genetics on paper becomes a fascinating and challenging form of mental gymnastics. A simple knowledge of the kinds of genes and how they are distributed on chromosomes is all that one needs to commence dreaming up problems of inheritance and writing down the specifications for the new kind of individual you wish to withdraw from nature's reservoir. The chance combinations in this reservoir are not limited to color in mice. The study of the structural abnormalities of the skin and fur, for example, can be exciting—and sometimes amusing.

"The most comical of all these mutants is the hairless. The hairless mouse spends the first two weeks of its life growing a full normal coat of fur and at this point cannot be distinguished from its normal brothers and sisters. Soon, however, the fur begins to drop out and the hair line swiftly recedes to complete baldness, so that in a few days the young mouse resembles a professor in a fur coat. Shortly the top of this coat is shed and the mouse seems to be wearing breeches. The final stage is perhaps the most amusing of all, for in a few days all trace of hair is gone except for a fringe about the haunches, and the mouse looks for all the world like a small, awkward ballerina. The entire loss is comparatively rapid and is completed in about 14 days. Thus four weeks after birth the creature has grown a coat and lost it—is finally as naked as a newborn baby. If there are no complicating factors, the mouse will soon regenerate a coarse fuzz which usually remains throughout its life. The first mice of this kind were caught in London in 1926.

"Some mice are not totally hairless, and yet are not completely furred. These have long fine fur which is much less dense than that of the normal mouse. In some the length of the fur is so reduced that it is necessary to use a magnifying glass to examine the quality of the fur.

"These strange characteristics are but a few of the interesting mutants which have appeared as the result of breeding two apparently uninteresting mice."

AS EARLY as 1814 Joseph von Fraunhofer, the father of astrophysics, placed a prism before the 1.2-inch lens of a theodolite and mapped the dark lines of the solar spectrum he saw, designating them with the now familiar letters. These are the Fraunhofer lines that give the stars the separate individualities of different human faces—individualities that are but dimly realized by those who observe only with a telescope. Unlike the telescope, the spectroscope reaches into a star and takes a sample of it. Paul W. Merrill of the Mount Wilson and Palomar Observatories has said that studying a star by telescope is like "trying to guess the contents of a book from its size, weight and general appearance; while a spectroscopic observation is opening the book and reading it through line by line."

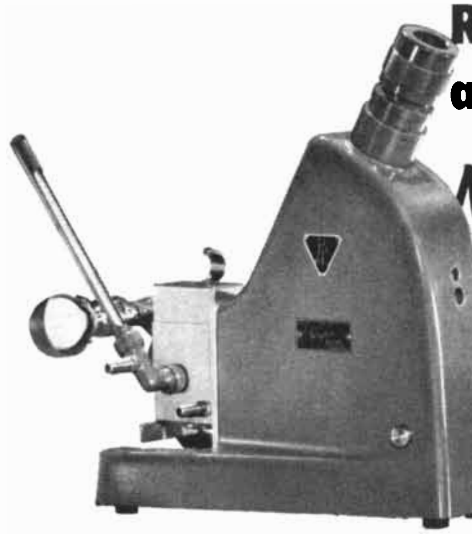
Today astrophysics, which deals with the physical and chemical characteristics of the stars, is the largest branch of astronomy; in fact, the astrophysical tail now wags the astronomical dog. Yet not one amateur astronomer in 100 attaches even a simple spectroscope to his telescope or seeks to become an amateur astrophysicist. True, much of astrophysics is abstruse, but not all of it. Getting started has been the chief obstacle.

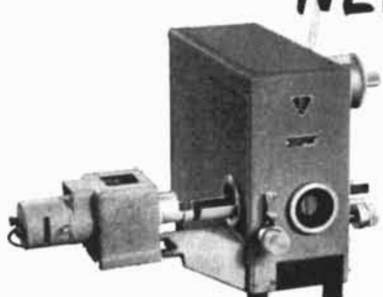
A simple way to get a start in astrophysics is to build the little ocular spectroscope described by Roger Hayward's drawing on the next page. With it you can study the spectra of the brightest stars, including the sun, directly or as reflected by the moon. This spectroscope will show the more prominent lines of the solar spectrum when held in the hand and aimed at the sun. But when you insert it in the telescope in place of the eyepiece, take care not to look through it directly at the sun, for that can make you blind. Without the telescope the spectroscope may also be used on light sources such as neon tubes, a salted gas flame or a welder's iron arc.

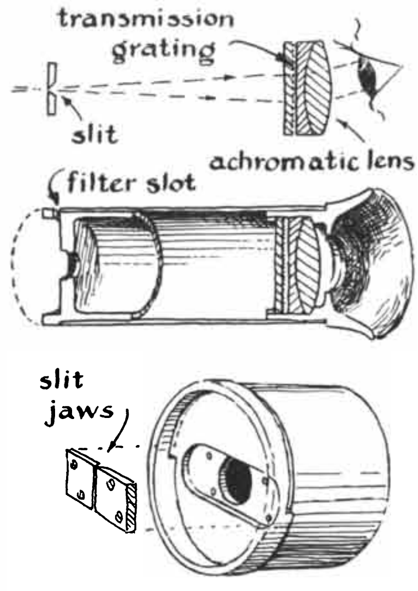
It is called an ocular spectroscope because its diameter is uniform with the standard telescope ocular, or eyepiece. It is kept with the set of oculars and adds variety to their use. Its multicolored diffraction-grating spectra will also serve to satisfy the astronomically unsophisticated visitors whom all telescope owners occasionally have to entertain and who, seeing only with their eyes and not with their understanding, fail to be impressed. The ocular spectroscope will make your Aunt Emma say "Ah!" even though she may never have heard of Kirchhoff's three laws of spectrum analysis.

The midget spectroscope was designed and built by Ernst Keil, an amateur astronomer and professional instrument maker at the California Institute of Technology in Pasadena, Calif. As an avocation he has from time to time designed and built little ocular spectroscopes, including one for James Fassero, the author of *Photographic Giants of Palomar,* who uses it in his lecture demonstrations with the 100-inch telescope at Mount Wilson.

The achromatic lens of about two inches focal length may be obtained from war surplus for a dollar or two, or a plano-convex lens may be substituted with little optical loss. The only working dimension is the 1¼-inch outside diameter, a carefully machined sliding fit for the telescope drawtube. The other dimensions are those you choose. There are no "blueprints." Keil supplies only the little round gratings, which are replicas made by his own process, developed years ago and different from others. "The replica film," he writes, "is an integral part of the







A simple ocular spectroscope

glass backing on which it is cast and is not a negative but a positive, giving the same distribution of light as the original." For a simple spectroscope a replica is as good as an original, and costs much less. The only way today to obtain a small original grating is to buy the costly laboratory spectrograph of which it is a part.

"The slit," Keil writes, "consists of two steel jaws made with care, their razor-sharp edges perfectly straight; see *Amateur Telescope Making*, page 248. The better the jaws, the sharper and more distinct will be the spectrum lines. Their separation will depend upon the brightness of the star observed, but .01 inch should be suitable.

"The light from a star is gathered by your telescope and focused in the plane of the slit jaws. Entering the slit, it passes through the transmission grating, which disperses it into its colors, then through a lens that collimates the light (making it parallel) and magnifies the spectrum. In this spectroscope the grating is put behind the collimator, instead of in front of it, to protect the grating. Actual trial will prove that in this simple spectroscope it makes no difference on which side of the grating the collimator is placed, for the spectroscope is not intended for serious scientific research but only for demonstrating the elementary principles of spectroscopy.

"To put the instrument in operation, first rotate the grating-lens unit, which must have a sliding fit inside the outer tube, until the grating lines are parallel with the slit. Then slide it in or out until the slit is in sharp focus. Insert it in the telescope and move it in or out until brilliant spectra appear.

"One available replica has 7,500 lines per inch and makes a spectrum of great intensity but comparatively small dispersion. Another, with 15,000 lines per inch, has about twice the dispersion of the first but a less brilliant spectrum.

"The slot on the front of the spectroscope is at right angles to the slit and of such a depth that a filter placed in it will cover one half of the slit. Two spectra, one above the other, will then be seen simultaneously—one the original, the other an absorption spectrum. Gelatin filters may be had from the Eastman Kodak Company or you can use red or blue cellophane, obtainable at photography stores."

A less serious addition to the amateur telescope owner's set of eyepieces was made by Alan R. Kirkham. He built a Tolles solid eyepiece lens of crystal quartz which is doubly refracting and produces two images. Thus he could always reveal a "secret area" of the sky where all the stars were double. An "eyepiece" built by Leo J. Scanlon consisted of a spinthariscope mounted inside an eyepiece shell. This is a particle of radium compound in front of a fluorescent screen of zinc sulfide, set behind the magnifying eye lens. Thus he could always show "exploding universes" through his telescope.

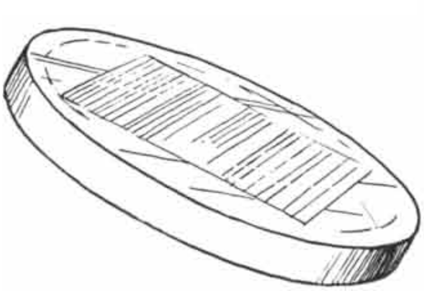
IT IS believed that most of the secret methods of making replicas of diffraction gratings, about which amateur telescope makers often inquire as if this department knew the secrets, are minor variations on basic methods long ago made public in *The Astrophysical Journal*. In 1905 Robert James Wallace of the Yerkes Observatory wrote in that periodical that T. Thorp of England in 1900 was the first to describe a presentable replica. Over the original grating he flowed a thin film of oil and then a celluloid solution which he left to dry. He then peeled off the thin, tough film and mounted it face up on glass with gelatin and glycerin, lowering the film gently and gradually into place. In the same volume of the same periodical Wallace described his own method. He flowed especially prepared collodion over the grating, allowed it to dry, stripped off the resulting film and mounted it on gelatin-coated glass.

In *The Astrophysical Journal* for March, 1910, J. A. Anderson described his own method. In the collodion he dissolved certain unnamed gums, then placed the finished replica face down on glass and heated the glass. The solution oozed into the grooves and hardened as a negative cast of the replica and positive cast of the grating. He then dissolved the glass between the ridges with hydrofluoric acid gas. These published methods are believed to have been the basis of the secret methods.

In 1937 the Perkin-Elmer Corporation developed the concave replica grating shown in the illustration on the opposite page. Its grating area is 2 by 2½ inches. These gratings are superior to the ordinary low-priced replica. They are made as shown in the illustration at the top of page 90. At the bottom is the glass support for the original grating and on it is the aluminum film in which the actual grating was ruled. The grating is greased and given an evaporated aluminum film. A liquid plastic fill of Laminac is then added. The supporting mirror for the future replica is placed on top of this and the plastic is polymerized by heat. The replica unit is then parted from the original grating at the level of the grease. Very high-grade replicas have recently been developed by the Bausch & Lomb Optical Company for use in large spectrographs.

Interesting experiments have been conducted in England by Sir Thomas Merton and L. A. Sayce. A very fine screw-thread is ruled on a steel cylinder with a diamond. The cylinder is then coated with cellulose acetate. When dry, the resulting film is slit lengthwise of the cylinder, peeled off like the bark of a tree, flattened and used as a high-grade replica. Details of this development are reserved for future description.

The replica method has often been suggested as an easy solution of the large grating problem. Those who propose it apparently overlook the fact that a large replica calls for an equally large and non-existent original grating. There is, however, a way to make a large grating from a small one. It is the composite grating, an example of which is depicted in the illustration at the bottom of the next page. (Such a grating, composed of four 5⅜ by 7¼ inch units, has been in use at Palomar Mountain.) This beautiful apple, however, is full of worms. While the spectrum from a composite grating is brighter in proportion to the number of units compounded, the grating has no greater resolving power than a single unit unless the demands of optics are met by a degree of mechanical precision that has not yet been attainable. Just how would the proponent of this method accomplish the following? He must manipulate the flimsy films on a backing of glass in such a way that the grooves in the upper right-hand unit in the illustration are in phase, or in step, within one millionth of an inch with the



The Perkin-Elmer replica grating

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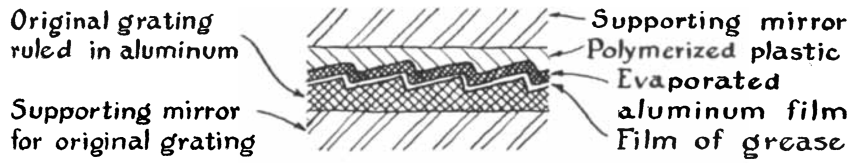


How the Perkin-Elmer replica grating is made

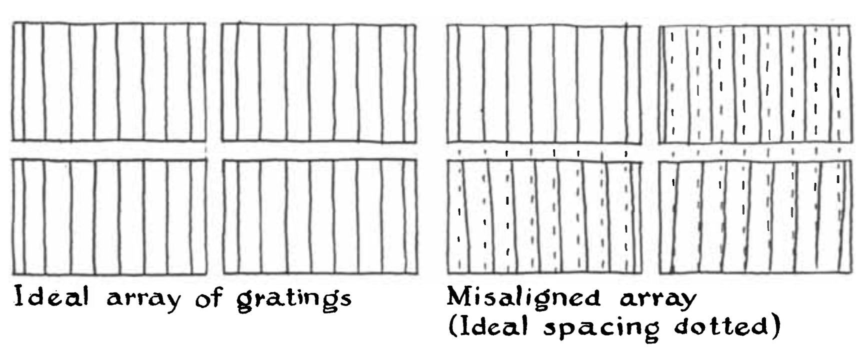
grooves in the unit at its left, regardless of the separation between the replicas. If he can accomplish this, his next job is to position the lower units similarly and make them colinear with all the upper units. Unless this geometric perfection of the whole is attained, the grating will remain essentially only a one-unit bright grating. The second complication is the exceedingly stiff optical requirement. For a 12-inch unit the glass backing must be flat to within a millionth of an inch, and for a 24-inch unit, to within one two-millionth of an inch. The composite is not a practical method of making a large diffraction grating.

THE refracting telescope has so many fine qualities that amateurs would be just as keen to make it as the reflecting type, if it did not require additional equipment: a lathe, spherometer, optical flat, preferably iron tools. It also calls for optical glass. High-grade, dependable optical glass has always been difficult for the individual small purchaser to obtain. Most of the glass types in the manufacturers' catalogues are sold only at wholesale or are monopolized by the manufacturers themselves. The amateur could have fun if he could range all through these attractive and expensively produced lists and order a little of this glass and a little of that and experiment with uncommon types. Instead, only two or three types are dealt out, sparingly and in but a few sizes. This throws the amateur's nose out of joint. On the other side of the ledger, the cost of paper work and correspondence (especially with amateurs!) renders these small retail sales uneconomical. The brief lists of glass are a compromise with the economics, made because the manufacturers personally admire the amateur's enthusiasm.

Under an arrangement made by this department, two additional types of glass in five diameters are now added to the amateur's limited list. They are manufactured by Chance Brothers, Ltd., of Birmingham, England. Chance Brothers' optical glass was used by W. F. A. Ellison and is the basis of his exposition of objective lens design in *Amateur Telescope Making*. The U. S. agency for Chance glass is no longer in existence, but no import license or other red tape complicates the purchase of a small pair of telescope blanks from abroad. The price is remitted by foreign postal money order. When the parcel arrives, the local letter carrier collects the import duty and leaves the parcel. The British prices have been adjusted to the 50 per cent *ad valorem* duty.

The following are the prices of crown and flint pairs: 3.3-inch postpaid at $6.33, 3.8-inch at $9.33, 4.3-inch at $14, 5.4-inch at $23.33 and 6.4-inch at $38.66, exclusive of import duty. The stated diameters are nominal, the respective clear apertures being 3, 3½, 4, 5 and 6 inches. For each size there is a choice of crown blanks: a hard crown with refractive index 1.519, dispersion 60.4, and a borosilicate crown with index 1.518, dispersion 64.1. The same dense flint, with indices 1.620 and 36.1, accompanies either crown. The glasses are "first quality," meaning, guaranteed completely free from striae. They are accompanied by full optical measured readings and melt number. The surfaces are smooth-ground.

Colonel Alan E. Gee, a widely known amateur and professional optician, points out that the hard crown and dense flint combination gives a secondary spectrum $f/3200$, the other combination, $f/2500$. Since the average criterion used in professional work is about $f/2400$, he considered the first combination "mighty good."



Geometric requirements for a compound replica grating

What GENERAL ELECTRIC People Are Saying

H. A. WINNE

Engineering

RESEARCH AND INDUSTRIAL PROGRESS: The number of industrial organizations that can support programs of fundamental research in their own laboratories is not great, but it is important that all industry recognize the importance of this type of research and support it in every way possible.

The extent to which industry fosters the kind of intellectual environment that is essential to creative work will determine, in a large measure, the dividends from research that it may expect to receive over the next 50 years.

The trick is to see around the corner—or, failing that clairvoyant sense, to make a fair guess as to what may lie just around the corner and to play the research program accordingly.

A research program that is well integrated with the business interests of the company is as much a part of the continuous operation of the business as is the maintenance of a plant that is well adapted to company needs. Consequently the research program must be protected from interruptions that might follow minor fluctuations in the business cycle.

Centennial Conf. on Ind. Research
Chicago, Illinois

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J. P. DITCHMAN

Lamp Division

APPLICATIONS OF LIGHT IN AGRICULTURE: Many people are working on the use of lamps and electrical traps as a means of crop insect pest control. Nothing is known of the sensation that insects experience when they see either colored or white light. Therefore, any intimation that insects have color perception should be avoided.

Literature on the movements of insects and other responses towards or away from the light sources is very fascinating because it shows that every conceivable variation of radiant energy, spectral distribution, orientation, quantity, duration, intensity, etc., may have some action on the insects or animals. Just to mention one of these with which we are familiar, the effectiveness of the light source in attracting nocturnal insects. Researchers in this field have indicated that most nocturnal insects have receivers that are sensitive to the blue and the ultraviolet part of the spectrum. This is being used to particular advantage in agricultural fields where sources of ultraviolet and visible blue are being used to attract the cornborer moth, cotton ball worm, and others to their destruction. The fluorescent black-light lamp has been so attractive in tests conducted during the last few years that the ordinary high-voltage traps being used to electrocute the moths have been clogged by the tremendous flight of the insects. Work has not progressed far enough to recommend this use to farmers to stop the scourge of these insects, but light traps are being used as indicators to give the farmer fair warning when he should use control measures against the flight of any particular pest.

Am. Soc. of Agricultural Engrs.
Chicago, Illinois

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W. R. G. BAKER

Electronics Division

MANAGEMENT OF RESEARCH AND DEVELOPMENT: Just as the progress of research and development cannot be measured in monetary terms, neither can it be measured in terms of numbers of engineers, or physicists, or chemists. It must be measured in the extension of human knowledge, and in the application of that knowledge. The trend today is to shorten the time between the extension of knowledge and its application, a task which becomes more difficult as we bring more important minutiae into our understanding.

There appears to be a growing recognition of the fact that time is a fourth dimension in scientific progress, and a dimension of increasing importance. The interrelation today of what were disassociated sciences yesterday is a strong indication that if the state of the art in one branch of science moves too far ahead, the expenditure of man-centuries of engineering effort may not produce marked further progress. A period of "catching-up" may well be required.

In many fields the developmental engineer is breathing down the neck of the man who is engaged in fundamental research. The obvious answer is to increase the number of qualified persons engaged in pure research in ratio to those engaged in applied research. This will not be possible to any great extent within the next few years.

Principally because of three factors: the high cost of research; the ever widening areas in which fundamental research can take place; and the shortage of trained engineers, several new operating procedures have been offered research management. The first has a variety of names such as techno-economics, or operations research. Basically this procedure is nothing more than the "task force" approach of studying all related areas, determining the extent of the new basic knowledge required, the effort needed to convert this knowledge to a usable form, the total capital investment and expected rate of recovery.

There is no reason why this approach should not be successful if those from whom you can reasonably expect progress in fundamental research, through reasons of adequate training and possession of an inquisitive mind, are available.

National Convention, IRE
New York City

AN INDEX OF ARTICLES AND AUTHORS

The following index lists all the articles and authors that appeared in Scientific American *during 1952. The index also lists the principal book review in each issue. Shorter book notes are not indexed.*

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.

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PORTAL CIRCULATION IN EXPERIMENTAL HEMORRHAGIC SHOCK: IN VIVO ROENTGEN RAY STUDIES. Edward W. Friedman, Howard A. Frank and Jacob Fine in *Annals of Surgery*, Vol. 134, No. 1; July, 1951.

ARROYOS

PRE-COLUMBIAN AGRICULTURE IN THE SOUTHWEST, AS CONDITIONED BY PERIODS OF ALLUVIATION. Kirk Bryan in *Annals of the Association of American Geographers*, Vol. 31, No. 4, pages 219-242; December, 1941.

Sought in Africa...discovered in Kalamazoo...

Following the discovery of the remarkable effectiveness of cortisone for the treatment of certain joint, eye and skin diseases, the world was searched for suitable raw material from which to make the drug. Expeditions, including one in which The Upjohn Company participated, were even sent to Africa because the seeds of a strophanthus plant were thought to contain a starting material that would make a number of difficult chemical steps unnecessary. No suitable seeds were found, but scientists in Kalamazoo discovered a mold that could be made to perform the key step in the synthesis of cortisone. Utilizing this mold a new method was perfected that makes cortisone available to more people.

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Photograph by Lee Aarons

The best gift of all

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Better health for our children, for example . . . greater protection against illness and suffering than any generation has ever enjoyed before. Better and more nourishing food to build sturdier bodies. Better shelter and clothing for greater comfort. New and broader opportunities for work and employment and achievement.

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