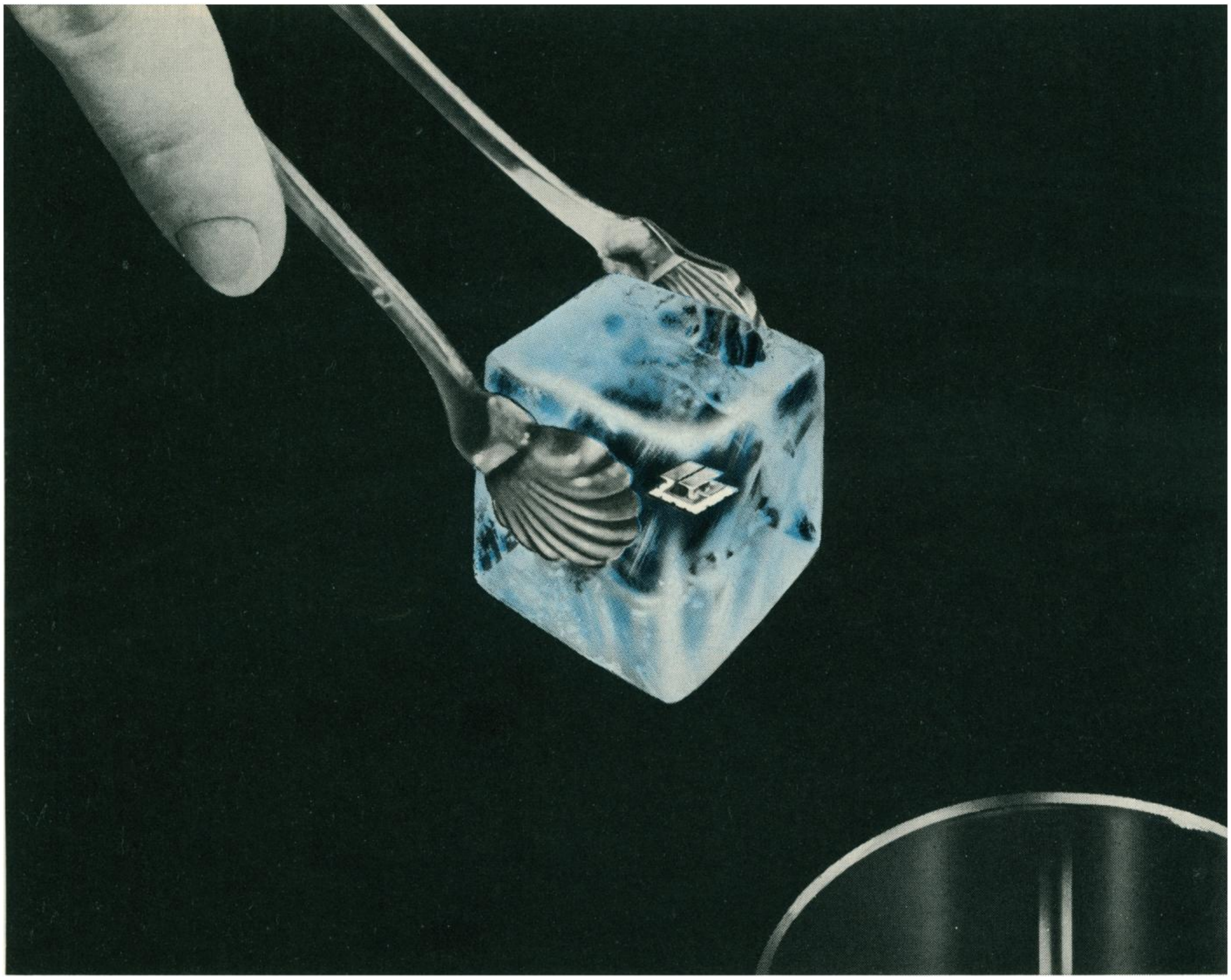
SCIENCE

21 June 1963
Vol. 140, No. 3573

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE



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COVER

An electron micrograph of three elementary particles of milker's nodule virus. The particles are negatively stained with 2 percent phosphotungstic acid adjusted to a *p*H of 4.9 with sodium hydroxide, washed briefly, and shadowed with palladium at an angle of 1:6 to bring out the surface detail. The surface pattern seems to be produced by a regular spiral arrangement of individual units (× 181,000). See page 1335.

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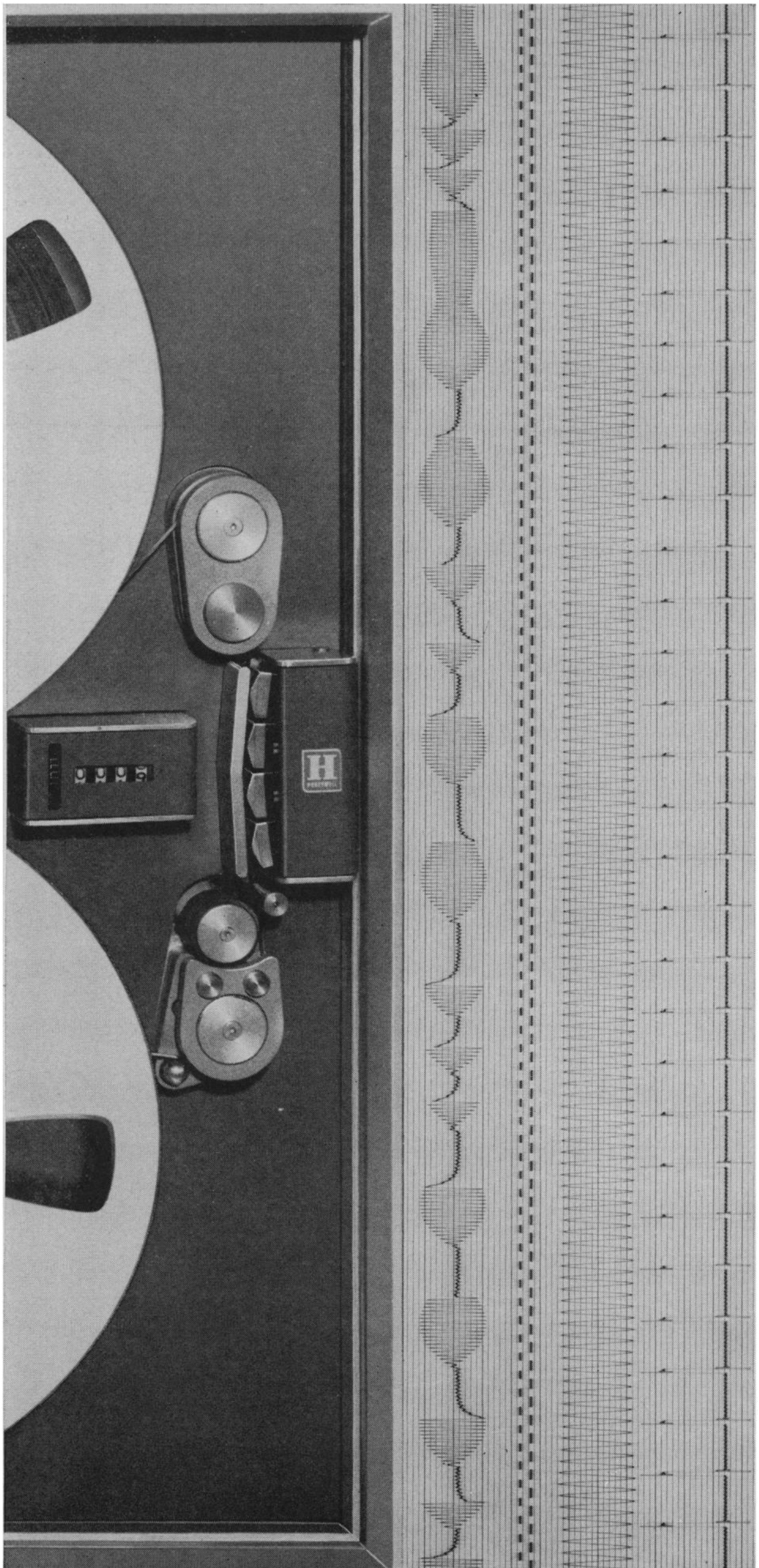

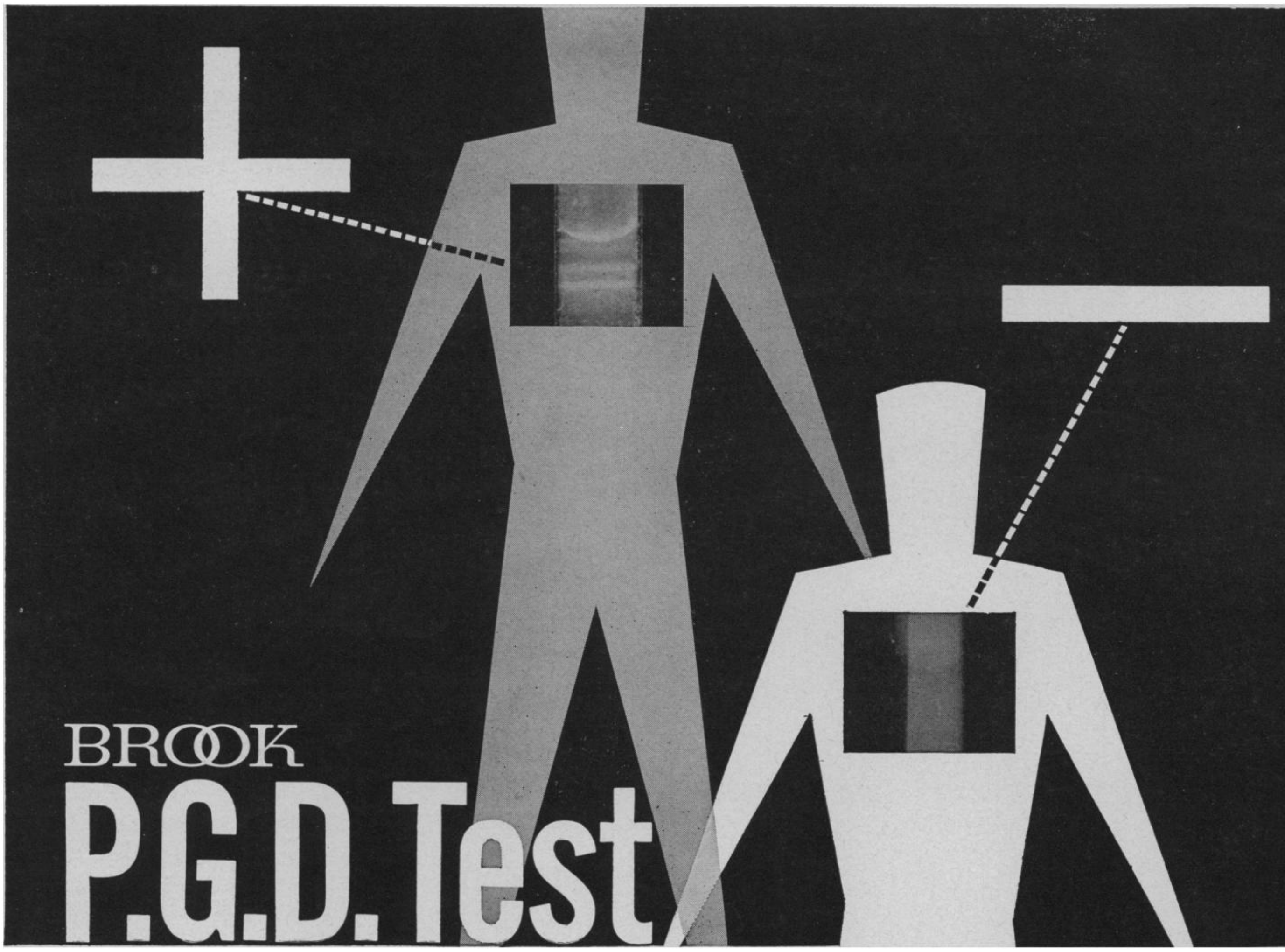
BROOK
P.G.D. Test

21 June 1963, Volume 140, Number 3573 **SCIENCE**

Creativity in the Sciences

Brains are our greatest resource, but we use them ineffectively. Most men and women develop only a small fraction—perhaps 10 percent—of their potential. Often one sees individuals do in a week, when inspired, what requires months at their customary pace. Discovery of means of utilizing talent more fully is perhaps the most important scientific advance that could be made at this time.

The creative individual must have a liberal portion of three qualities: mental capacity, judgment, and motivation. By mental capacity is meant something related to intelligence quotient, but something not precisely measured by any of the standard tests. Almost all creative scientists probably have I.Q.'s of 130 or above. Mental capacity is, of course, largely genetically controlled. Judgment is an important characteristic in a scientist. In research one is continually faced with multiple choices as to what experiment to do next and how to do it. The effort that goes into a sterile experiment can be as great as that which goes into an illuminating one. Some gifted individuals have a knack for selecting the most fruitful approach. The quality of judgment is also probably genetically controlled, but the individual can improve his endowment with experience, and he can tap the wisdom of others. I have noted even gifted individuals checking their estimate of a situation in discussions with their colleagues. Motivation is the factor in creativity which is most subject to change by one's surroundings. It is also an essential component, for without it the best minds accomplish little. With adequate motivation comes the self-control necessary for tapping one's resources.

Creative effort differs from most other activities in that it generally requires unusual discipline. People in other walks of life can go for long periods without exerting much self-control. No foreman can successfully direct a creative scientist in detail how to cerebrate or tell him what move to make next. The judgment and initiative must stem from the individual. He must do the necessary thinking, and if he is to be truly creative he must think deeply and organize himself and his activities. If he fails to exercise proper self-discipline, this deficiency is not obvious to others immediately. He may appear for work as usual, follow his accustomed routines, attend seminars, read the literature, and give the appearance of creative effort. But this activity may be only a facade if his mind is elsewhere.

Related to the need for self-discipline are qualities of patience, courage, and willingness to take the punishment of disappointment. In the present era of science there is pressure to build extensive bibliographies. The certain way of doing this is to carry on research which is merely a small extension of what is already known. Under these circumstances the scientist is not forced to think deeply, yet he feels some security as a contributor to science. Little in the way of creativity comes out of such procedure. The path of courage lies in choosing a difficult but fundamental problem and working at it even though the walls of confusion seem insurmountable. The person who undertakes such a task must be capable of living with disappointment. He must be able to cope with the unhappiness that follows the failure of what seemed to be promising approaches. Even after an extended period of apparently fruitless work, he must be capable of summoning the necessary stamina to continue his efforts. The inner resources which permit the creative person to continue after repeated failure can stem only from deep motivation.—P.H.A.

This editorial is based on an address given at the New York University Conference on Education for Creativity in the Sciences, 13–15 June 1963.

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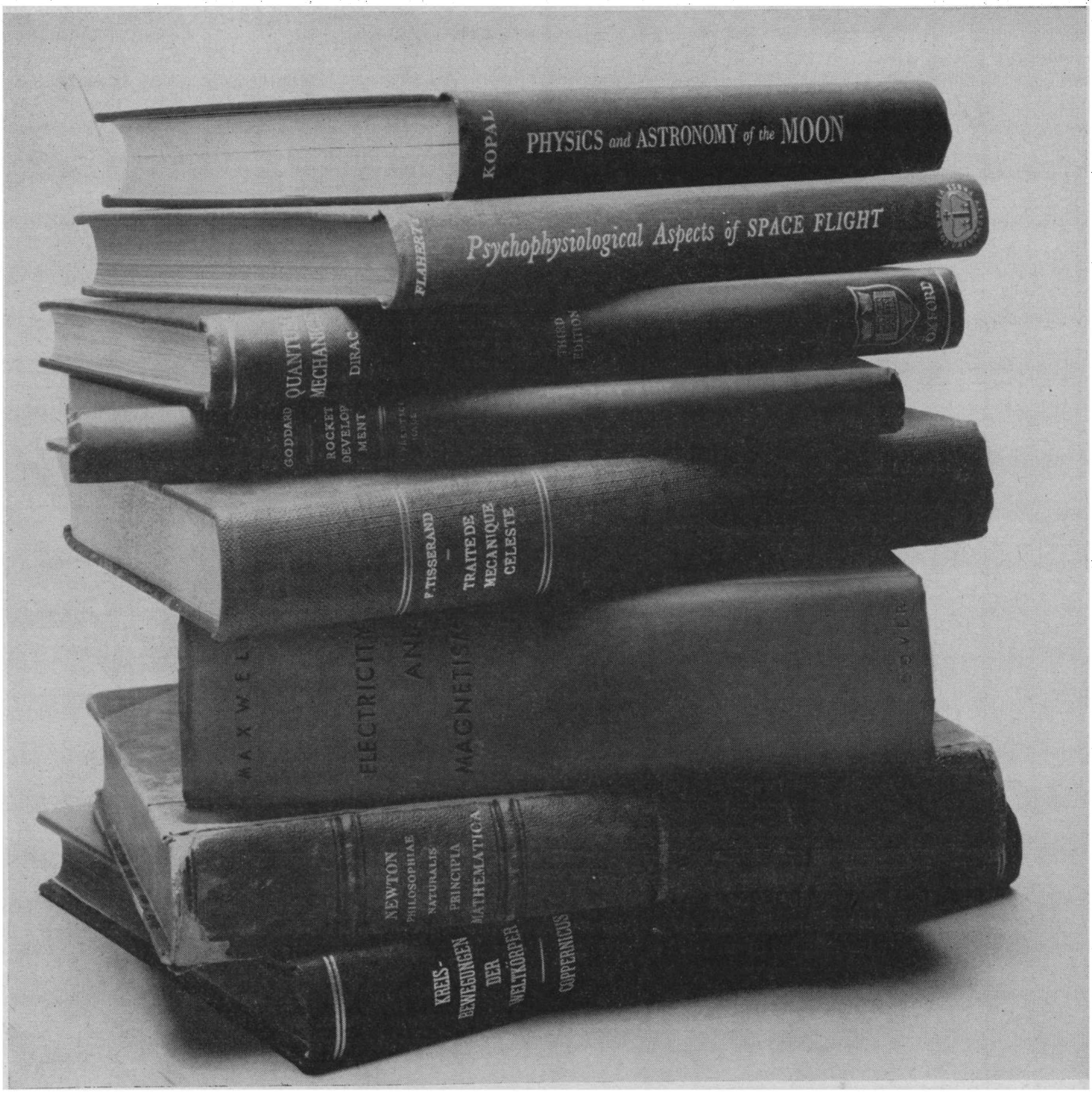
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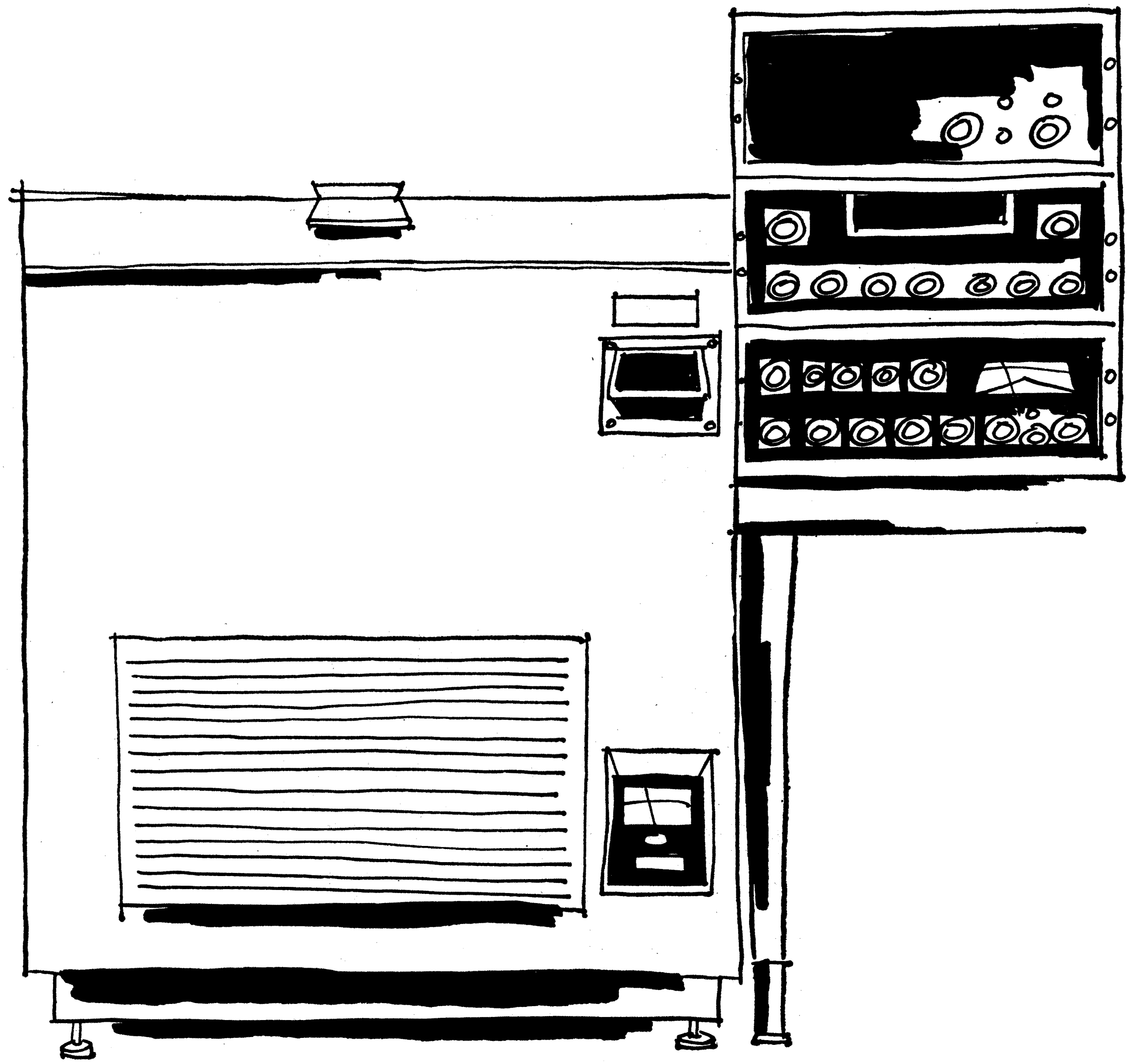

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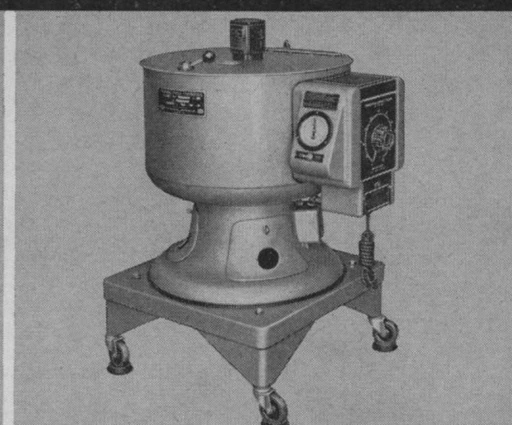

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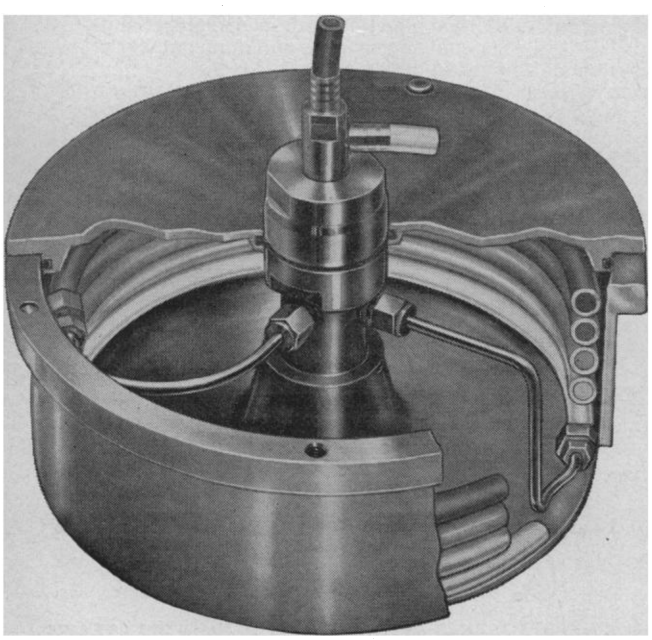

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fied there. The Public Health Service program concentrates on six general areas: (i) scientific publications, (ii) unpublished information, (iii) abstracting and indexing services, (iv) evaluation of scientific information, (v) the information clearing house, and (vi) information service centers.

Philip H. Abelson, editor of *Science*, addressed the audience on "An editor's view of publication problems." The primary publication as the source document for formal scientific communication is a critical point in the entire process and the quality of such publication is directly related to the meticulousness with which the refereeing process is carried out. This varies widely from journal to journal. In addition, journals must be well funded either through private sources, subscription income, page charges, or some combination of these if the editor is to be able to discharge his responsibilities to his journal and to the scientific community both promptly and efficiently.

Raymund L. Zwemer (American Physiological Society) summarized some of the "New approaches to 'keeping up' with the literature." These included, in his view, such elements as permuted indexing and variations thereof, key word indexing, source indexing, and translation services, both cover-to-cover and selective, as well as the conventional abstracting services. The value functions of these several approaches were explored in some detail and the problems of their effective implementation reviewed.

"Current trends in documentation research" was the subject of the fifth paper presented by Harold Wooster (Air Force Office of Scientific Research), who discussed some of the more important modern methods under study. These involve the application of both computer techniques and other methodologies to such problems as chemical structure storage and search, mechanical translation, optical scanning to facilitate input to machines, and the various alternatives being considered as potential substitutes for the present scientific journal. It is perhaps significant that a very large number of enterprises listed in the National Science Foundation roster of current activities in research and development are being supported by agencies such as the Air Force Office of Scientific Research. This phenomenon necessarily focuses attention on the great and growing importance of the informal report literature generated in such voluminous quantities as a result of government-financed programs in science and technology.

The symposium concluded with a statement of the importance of the problem from the viewpoint of the national interest, presented by Julius N. Cahn (director of the Medical Research project of Senator Humphrey's Subcommittee on Reorganization of the United States Senate Committee on Government Operations). Cahn underlined the importance with which the government views the information problem and its vital interactions with the health and welfare of the nation. With the real understanding exhibited by the Senate Committee and its appreciation of the problems before the scientific community, the outcome of the Committee studies may be expected to provide a continuing impetus for greater accomplishment by the scientific community.

The symposium was outstanding in the sense that the audience it attracted contained predominantly working scientists rather than professional documentalists, information specialists, or librarians. Effective progress in battling the "exploding literature" can only be attained to the extent that the working scientist is aware of the problem and appreciative of the necessity for taking effective steps to overcome it. Any forum, therefore, which brings the problem to the working scientist and enlists his sympathetic understanding represents an important contribution to the attainment of better solutions.

The papers presented at the symposium will be published later this year in *Federation Proceedings*.

ROBERT A. HARTE
American Society of Biological Chemists, Washington 14, D.C.

Blood Flow

Physiologists, engineers, mathematicians, and physicists from the United States and seven foreign countries attended the first international symposium on pulsatile blood flow which was held at the Presbyterian Hospital in Philadelphia, 11 to 13 April. Recent progress in the dynamic analysis of blood flow was reviewed, the present state of our knowledge of the field was re-evaluated, and the existing problems and their possible solutions were outlined.

The transducer recording systems used for accurate evaluation of pulsatile flow must meet considerably higher requirements than those which are generally considered satisfactory. A flat frequency response from 0 to 30 cycles per second is absolutely necessary. The present state of manometry and displacement measuring devices is probably adequate provided extensive care is exercised both for their static and dynamic calibration. The damaging effects of minute air bubbles on manometer behavior are still not generally realized.

The performance of flow-metering devices, on the other hand, is far from satisfactory. Two main problems must be solved before either the electromagnetic or the ultrasonic flowmeter can be used with confidence for such studies. Although the calibration of electrical performance can be carried out with relative ease, the dynamic calibration of the whole electromechanical system is fraught with difficulties. Adequate volume displacements at the required frequencies necessitate powerful pumps, the output of which must be exactly known. Although such devices can be built, they are likely to be considerably more expensive than the flowmeters themselves.

The second problem relates to our ignorance about the distribution of velocity profiles in various types of flows and cross sections. Theoretical considerations indicate that errors of up to 25 percent may be introduced if the velocity profile used for the calibration is significantly different from the profiles actually encountered during the experimental measurement. Additional questions which are at present not too well understood include the effects of hematocrit, wall thickness, temperature, blood chemistry (ionization), vessel fit, field frequency and wave shape, electrode character, and contact potential upon flowmeter performance.

Since minor errors in amplitude and phase lead to significant differences in some of the calculated parameters, a better understanding of these effects is essential for a reliable interpretation of observed results. Considerably more theoretical and experimental work is necessary before these effects can be properly evaluated.

Theoretical and experimental approaches to pulsatile flow have shown that blood flow through the vascular bed depends only upon two parameters, the driving pressure and the impedance of blood and vasculature. The driving pressure is, of course, provided by the pumping action of the ventricles, so that the impedance describes the overall behavior of the vascular bed and its content and includes explicitly the inertial and viscous properties of the fluid as well as the physical characteristics of the vessel wall. A theoretical analysis of this behavior was carried out by Womersley only a few years ago, and experimental results presented at this meeting indicate that Womersley's theory underestimates the frictional losses in pulsatile flow. These differences may result from the fact that the individual vessels taper, that turbulence is present during at least part of the cardiac cycle, and that the vessel wall is viscoelastic. A powerful analysis of the tapering effect was presented.

While this approach is very promising, a number of refinements are necessary until the predictions resulting from this theory are as good as those obtained from Womersley's work. In uniform, elastic tubes, the pressure flow behavior can be predicted by classical theory. As soon as nonuniformities such as changes in wall thickness, vessel diameter, or branching are introduced the observed results become quite different from those expected from theory, even in relatively simple models. The nonuniformity of the vascular tree is not limited to geometrical factors alone; it also includes progressive stiffening of the vascular wall toward the periphery. There are significant species differences: the Windkessel might be an appropriate model for the domestic turkey but quite unsatisfactory for mammals. Few quantitative data on the behavior of smooth vascular muscle are available at present, but its influence upon the physical properties of the vessel wall may account for an increased pressure wave transmission in the smaller blood vessels.

The blood flow through the vessel wall is another factor which has been neglected until recently even though it is well known that coronary blood flow changes widely from cardiac systole to disatole. Similar effects may be expected in the arterial wall and may result in variations of its mechanical behavior. Model experiments in tubes with circular and elliptic cross sections indicate that even minor deviations from a circular cross section may introduce serious inequalities in the distention of viscoelastic tubes. These inequalities

reach a maximum in the ellipse where the two semiaxes change in opposite direction during the pulsatile cycle. Further investigation is necessary to determine how far these results apply to various vessels *in situ.*

In hydrodynamics the Reynolds number defines the ratio between inertial and viscous forces and its critical value, a condition which is necessary to maintain turbulence. This condition can, however, only be evaluated if the flow channel is long with respect to its hydraulic depth. In the vascular bed this ratio is quite small, and it is therefore of minor importance if the introduced disturbances maintain themselves or die out after having traveled a certain distance, since new disturbances will already have been introduced over this interval. Birefringence studies indicate that, in pulsatile flow, turbulence in tubes of the size of the larger vessels appears already at mean velocities of 20 to 30 centimeters per second—that is, values which are certainly exceeded over most of the systolic part of the cycle. Additional turbulence is introduced at any branch point.

Measurements of pressure gradients at these flow rates in distensible tubes indicate that the turbulence observed by the birefringence technique may alter the pressure-flow relations considerably. The production of turbulent flow in pulsatile flow depends not only on the hydraulic depth, kinematic viscosity, and mean velocity, but also on the frequency and amplitude of the superimposed oscillations and on the physical properties of the wall. For an evaluation of the latter, the shape of the actual cross section has to be considered.

These problems are as much of a challenge to the mechanical engineer and hydrodynamicist as to the vascular physiologist. Powerful methods are available for study, but requirements exist not only for exquisite instrumentation and extensive computer facilities, but also for multidisciplinary manpower.

This symposium has been another demonstration of the advantages in combining several disciplines into one team, provided the problem is properly defined. It was supported by grant HE 07692-01 from the National Institutes of Health. The proceedings will be published this fall by the McGraw-Hill Book Company.

E. O. ATTINGER

Presbyterian Hospital in Philadelphia, Philadelphia, Pennsylvania