SCIENCE SERVICE CONFERENCE[1]

ARE the social sciences really sciences? Can economics and the other studies that bear immediately and intimately on human affairs be handled with the same detached objectivity that is possible to a physicist or to a biologist? This question became the subject of a brief friendly debate between a noted physicist and an equally noted economist at the dinner following a conference called by Science Service to discuss possible improvements in the transmission to the public of scientific news and information.

The question was first raised during the afternoon conference by Robert P. Scripps, editorial director of the Scripps-Howard Newspapers, whose father, the late E. W. Scripps, was the founder of Science Service. The ruling idea in his father's mind when he launched the enterprise, Mr. Scripps said, was to benefit humanity by the wider dissemination of scientific knowledge and method; and he suggested, as in line with this tradition, the possible advisability of adding the so-called social sciences to the scope of Science Service's work.

In his evening address, Professor Robert A. Millikan, director of the Norman Bridge Laboratory of the California Institute of Technology, expressed frank doubts as to whether the social sciences are really scientific. The thing that really characterizes a science, he said, is the existence of a large body of facts, a universally accepted doctrine. A science such as physics, he pointed out, is based on such a body of facts, and though this basis may be added to, the later additions work no essential change in the earlier known truths. There is, of course, always a margin of disagreement, usually over new developments, but as compared with the main body of the science this is very narrow indeed.

In economics and the other social sciences, Dr. Millikan held, an exactly opposite condition obtains. The body of agreed-on doctrine is vanishingly small, and the field in which experts disagree comprises almost the whole of the science. Furthermore, the disagreement extends beyond questions of fact into the lightning-charged field of the emotions and human passions, so that the conflicts arising therein are much more intense than they are in the more academic realm of the physical sciences. For this reason, the speaker concluded, it would seem inadvisable, perhaps dangerous, for an organization like Science Service to undertake an extension of its activities into the social science field at the present time.

Dr. H. G. Moulton, president of the Brookings Institution, Washington, D. C., spoke as an active champion of the social sciences, both as having an intimate and potentially useful bearing on human life and as being susceptible to a really scientific approach. Economics was once as definite a science as physics, he said, at least so far as having a definite basis of agreed-on doctrine is concerned. It has only been during the past one or two generations that this apparently solid basis has been dissolved by the revolutionary changes brought about by recent world events. The facts of economics and the other social sciences are still there, he insisted, and still capable of the impartial and objective treatment demanded by true scientific method. He felt that they constitute a challenge to an institution for the popular dissemination of knowledge, like Science Service, and that work in this field would be a quite proper undertaking.

The remaining discussion during the evening session was given an entirely different turn by Dr. John H. Finley, editor of the *New York Times*. He spoke of the problem from an editor's angle, stressing the constant necessity of working with speed yet with accuracy, of maintaining a balance of material selected, of watchfulness against propaganda from any source, and of the editor's need to "know a little about everything, and to know where to turn to find out everything about anything."

Dr. William H. Welch, dean of the medical faculty of the Johns Hopkins University, presided at the evening meeting.

During the afternoon session, a succession of five-minute talks by various eminent scientists and representatives of the press set forth a symposium of views on the more immediate problems involved in getting correct information on scientific advances and scientific methods before the general public. The conference was held in the building of the National Academy of Sciences, immediately after the close of the spring meeting of the Academy, and a majority of the scientists present were members of that organization, often called "the Senate of American Science."

In opening the discussion, Dr. J. McKeen Cattell, editor of SCIENCE and president of Science Service, paid a tribute to the late E. W. Scripps and to Dr. William E. Ritter, of the University of California, as co-founders of Science Service. "If Scripps was the Charlemagne who could do all this with a high hand, Ritter was the Alcuin who advised him." Attention was also called to the part taken in the founding of the service by Drs. George E. Hale, Robert A. Millikan, A. A. Noyes and Vernon Kellogg and the invaluable work of the first director, Dr. Edwin E. Slosson.

Then, in rapid succession, the scientists and newspaper men voiced their opinions and suggestions.

Dr. Simon Flexner, director of laboratories of the Rockefeller Institute for Medical Research, New York

[1] Reported by Science Service.

City, spoke of the need for more than ordinary precaution in handling medical news, and suggested the advisability of submitting all items to an advisor well qualified in medical science before publication.

Dr. Karl T. Compton, president of the Massachusetts Institute of Technology, expressed the wish that scientific institutions and organizations might "feed in" important and desirable news items, so that they may receive prompt and adequate public notice.

Dr. Frank B. Jewett, president of the Bell Telephone Laboratories, spoke on the necessity of informing people not only on new scientific discoveries but on scientific method and outlook as well. The rulers of the world are uninformed of the natural forces that control the world, he said, and much of the present crop of disastrous legislature is such simply because it runs counter to natural laws. If it is to be avoided and wise laws passed, the lawmakers must be given the information they need.

A. H. Kirchhofer, editor of the Buffalo Evening News, spoke as a representative of the press. He asked for more mutual tolerance and patience between scientists and newspapermen, and expressed the belief that news stories on scientific subjects would be more satisfactory both to editors and to scientists if the latter would give intelligent reporters their cooperation.

Dr. John C. Merriam, president of the Carnegie Institution of Washington, after warning newspapermen against trying to make "good copy" and big headlines out of researches still in the discussion stage, concluded with the suggestion that the knowledge of interest by the public in such unfinished problems may stimulate scientists to express their findings more clearly and understandably when they finally reach them.

Dr. A. A. Noyes, director of the Gates Chemical Laboratory of the California Institute of Technology, made two suggestions: first, the desirability of making clear the evidential status of any announcement put forth as a news item; second, the possibility of using younger scientists in the various laboratories and universities as local correspondents.

Professor E. B. Wilson, of Harvard University, called attention to the differing aspects of the concept of accuracy, depending on the audience to whom a given scientific discovery or fact is to be presented. Details that are absolutely essential before a group of scientists may only befog the picture if they are used before a lay audience, and thus destroy instead of make for accuracy in the image that gets into the minds destined to receive it.

Dr. Charles G. Abbot, secretary of the Smithsonian Institution, registered strong approval of a new Science Service enterprise, the distribution of low-priced phonograph records giving brief talks by leading scientists, and expressed the hope that further issues of this sort would be made.

Dr. W. F. G. Swann, director of the Bartol Research Foundation of the Franklin Institute, Philadelphia, voiced his faith in the ability of "the man in the street" to understand science if it is properly presented to him. "I would much rather talk about relativity to an intelligent lawyer or an intelligent clergyman than to a bad physicist," he said.

Dr. Francis G. Benedict, director of the Nutrition Laboratory of the Carnegie Institution of Washington, in Boston, stressed the desirability of care and accuracy in reporting medical discoveries, because of the great immediate importance of these to human life, and the possible lamentable consequences of even apparently minor error.

Dr. Paul R. Heyl, of the U. S. Bureau of Standards, suggested that general summaries or reviews of progress in science might be well received, and would be useful to scientists as well as to the lay public.

Professor A. E. Kennelly, of Harvard University, called attention to possible errors of impression that readers might receive if undue emphasis is placed on the wrong point in reporting a scientific discovery or event. He also made a plea for the expression of quantitative results in the metric system, which he termed "the international language of science."

Professor Charles R. Stockard, of Cornell Medical College, reinforced previously expressed pleas for a high degree of accuracy in reporting medical news. He further suggested the desirability of explaining properly how animal experimentation is used in working out medical advances, as a counter to anti-vivisection propaganda.

Professor Joel H. Hildebrand, of the University of California, expressed his desire that science articles intended for the general public give not merely the news of discoveries but that they also stress the importance of the scientific method in thinking and working.

Dr. T. Wayland Vaughan, director of the Scripps Institution of Oceanography, La Jolla, California, declared that his relations with the press had always been satisfactory, because he was willing to meet intelligent newspapermen half way. He recommended cooperation to his fellow-scientists.

Professor Richard M. Field, Princeton University geologist, called attention to the natural interest of the public in the economic aspects of science, and in economic questions generally.

Dr. F. P. Keppel, president of the Carnegie Corporation, commended Science Service for having "stuck to its last," and said he hoped it would continue to do so.

Dr. F. G. Cottrell, chemist and inventor of the precipitation process, laid fresh emphasis on the necessity of presenting science as news to newspapers.

Capt. J. F. Hellweg, of the U. S. Navy, spoke briefly on "what should not be printed."

Professor Knight Dunlap, of the Johns Hopkins University, contrasted conditions in science news reporting since Science Service entered the field with what they were before that time, and expressed the hope that this organization would continue its work independently, not only for the work it is doing itself but for its stimulating effect on the science reporting of the other newspaper syndicates.

Dr. W. H. Howell, of the Johns Hopkins Medical School, chairman of the executive committee of Science Service, closed the discussion with an expression of thanks to his fellow-scientists for their cooperation in the work of Science Service.

SCIENTIFIC APPARATUS AND LABORATORY METHODS

A CRITIQUE OF THE SERIAL DILUTION METHOD FOR QUANTITATIVE DETERMINATION OF BACTERIOPHAGE

THE two current methods for quantitative determination of bacteriophage are the plaque count and the serial dilution technique. The latter procedure involves testing successive dilutions of the lytic principle for ability to produce visible lysis of a broth culture of susceptible bacteria. The final effective dilution is assumed to contain at least one phage particle and the titre of the original lysate is calculated upon this basis.

For the plaque count, phage dilutions are plated upon a substrate of susceptible organisms. The resulting punched-out, bare areas in the surface growth are considered to represent the loci of single phage particles. Their number, together with the dilution factor, should theoretically furnish a simple means of estimating the total phage/ml. in the sample.

That agreement between the two methods above outlined is far from satisfactory for quantitative work is apparent from a survey of the literature. Further, the use of either procedure alone does not permit of accurate comparative determinations. In the case of the plaque count it has been pointed out by Bronfenbrenner [1, 2] that there are several factors not amenable to ready control which effect the formation of plaques; consequently, checks are difficult to procure.

The serial dilution technic presents similar limitations. Clark[3] has analyzed the method upon purely statistical grounds and concludes that with a dilution factor of 0.1 only 60 per cent. of parallel runs on the same solution should give an identical end-point. It is shown in the present paper that some of the difficulties encountered in practical application of the method are explicable on the basis of the kinetics of the bacterium-bacteriophage reaction.

The chief points established regarding the mechanism of phage action, as exemplified by susceptible Staphylococci growing in the presence of anti-Staphylococcus phage, may be briefly summarized as follows:

(1) Phage formation is conditioned by bacterial growth.[4]

(2) The percentage rate of increase in phage is proportional to the percentage rate of increase of bacteria, *i.e.*,

$$\frac{dP}{Pdt} = C\frac{dB}{Bdt.}$$

(3) Phage accumulates within the bacteria, meanwhile maintaining equilibrium with phage in the broth outside the cells, until a certain concentration of phage per bacterium is attained, when lysis ensues. There is thus a definite lytic threshold.[4, 5]

(4) Phage is distributed between susceptible cells and the fluid medium in two ways depending upon whether the bacteria are alive or dead. With live cells (resting or growing) distribution is of normal type and diffusion of phage, into or out of the organisms, proceeds according to a definite quantitative relationship. If the cells are dead, however, they adsorb phage irreversibly and equilibrium may be represented in terms of the Freundlich adsorption isotherm equation.[6]

The purpose of the serial dilution procedure is to ascertain the highest effective phage dilution capable of initiating visible lysis in the test suspension and consequently the technique has been assumed to rest upon a qualitative test for the presence of phage. However, in the case of the organism and phage studied, the qualitative test is conditioned by definite quantitative factors and in effect does not determine whether phage is present or absent in the higher dilutions but rather whether or not a certain minimum quantity of phage is present. This amount is not constant but varies with test conditions.

Consideration of two cases will clarify the above statement. Keeping in mind the dependence of lysis upon development of a certain high intracellular con-

[1] J. Bronfenbrenner and C. Korb, *J. Exp. Med.*, 42, 483, 1925.

[2] J. Bronfenbrenner and C. Korb, *Proc. Soc. Exp. Biol. and Med.*, 21, 315, 1924.

[3] H. Clark, *J. Gen. Physiol.*, 11, 71, 1927.

[4] A. P. Krueger and J. H. Northrop, *J. Gen. Physiol.*, 14 (No. 2), 223, 1930.

[5] J. H. Northrop and A. P. Krueger, *J. Gen. Physiol.*, (in press).

[6] A. P. Krueger, *J. Gen. Physiol.*, 14 (No. 4), 493, 1931.